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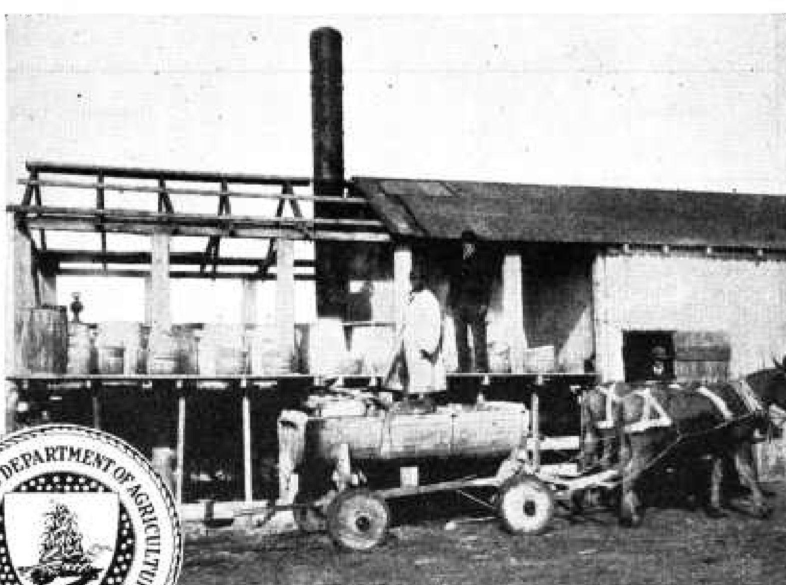
LIME-SULPHUR CONCENTRATE

Preparation, Uses, and Designs for Plants



ANY FRUIT GROWER who is equipped with the proper apparatus can readily prepare lime-sulphur solution for spraying. The equipment need not be elaborate or expensive where small quantities are to be made, since a first-class concentrate can be produced in an ordinary iron kettle suspended over a wood fire. In the first part of this bulletin will be found formulas and suggestions for the making, storing, and diluting of lime-sulphur concentrate. In the latter part suggestions are given on the building of several types of cookers of different sizes, ranging from a very simple 25-gallon kettle to steam plants in which 800 gallons of the concentrate can be prepared in one cooking.

Washington, D. C. December, 1922

LIME-SULPHUR CONCENTRATE.

Preparation, Uses, and Designs for Plants.

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CONTENTS.

A VALUABLE SPRAY, EASILY PREPARED.

LIME-SULPHUR solution [1] has deservedly won a high place among our present-day orchard spray materials, and is probably used more extensively than any other compound, since it is both an insecticide and a fungicide, effective against certain insects and diseases. It is used during both the dormant and growing seasons. Moreover, lime-sulphur is comparatively cheap, and fortunately can be combined with many other compounds, such as arsenate of lead and nicotine, for the simultaneous control of chewing and sucking insects and certain fungous diseases. Its chief disadvantage is that it is disagreeable to use, owing to its causticity. As the name indicates, it is composed of lime and sulphur, and it is made by boiling these materials together in the presence of water. The chemical changes that take place during the operation are somewhat involved, but the actual process of making the concentrate is comparatively simple.

[1] Lime-sulphur solution described in this bulletin should not be confused with the so-called self-boiled lime-sulphur, which is extensively used in summer spraying of peach trees. The self-boiled lime-sulphur is a mechanical mixture of lime and sulphur, whereas lime-sulphur solution is a chemical combination.

USES OF LIME-SULPHUR.

DORMANT SPRAY.

During the winter or dormant period of deciduous fruit trees lime-sulphur is widely used by fruit growers for the control of the San Jose scale and pear-leaf blister-mite. It is also of value against the oyster-shell scale and the scurfy scale. As a fungicide the dormant application of lime-sulphur is very effective in preventing peach leaf-curl.

DELAYED-DORMANT SPRAY.

Many fruit growers do not apply the dormant spray until the apple-bud tips show green. At this time many of the aphids have hatched and have clustered on the tips (Fig. 1) where they may be killed if nicotine is added to the lime-sulphur solution. Thus the orchardist controls both the scale insects and aphids in the one application instead of making two separate treatments. Care should be taken, however, to complete the spraying by the time the leaf tips begin to separate, since the aphids crawl to the base of the leaves as they unfold and are thus more or less protected from the spray; also, if the delayed-dormant treatment is made too late, the lime-sulphur is likely to burn the expanding foliage. In large orchards and where scale insects are serious, it is not always expedient to delay the dormant treatment until this time, since unfavorable weather conditions may interfere with the complete covering of the orchard within the prescribed period.

FIG. 1.—Aphids clustered on expanding apple bud; proper time to make delayed-dormant spray. Considerably enlarged. (Quaintance and Siegler.)

SUMMER SPRAY.

When trees are in foliage lime-sulphur, at appropriate summer strengths, may be used on all pome fruits, and is of value chiefly as a fungicide for certain diseases, notably apple scab. Its use in the summer also aids in reducing the San Jose scale. For the prevention of leaf-spot of the sour cherry the same strength as that used on the apple should be applied, but on the sweet cherry a weaker spray should be used. (See dilution table, p. 11.) Lime-sulphur solution should never be used on peaches or Japanese plums when the trees are in foliage.

HOMEMADE VERSUS COMMERCIAL CONCENTRATES.

GENERAL COMPARISON.

The chief difference between the homemade product and that sold commercially is in the density of the solutions. The commercial

concentrates are usually of a uniform density, testing from about 32° to 33° Baumé, whereas in the homemade solutions the density may vary from 23° to 34° Baumé, depending upon the formula used, the purity of the lime and sulphur, and the care with which it is made. From this it should not be inferred that the homemade product is inferior to the commercial, but if of a weaker strength more of it must be used to compensate for its lower sulphur content. The commercial concentrate is usually a clear, cherry-red liquid, its clarity being due to its having been drawn from settling tanks and carefully strained or filtered. The homemade concentrate is not usually so clear, owing to the presence of a dark greenish, cloudlike sediment, which, however, is so finely divided that it is nowise objectionable.

MAKING LIME-SULPHUR ON THE FARM.

It is impossible to state definitely the conditions under which it is profitable to make lime-sulphur concentrate on the farm. Some orchardists contend that for the average owner there is no economy in doing so. Exceptions to this opinion, however, are manifested by the comparatively large number of home plants that may be found in orchard sections. Unless a grower lives near a commercial plant or factory where this solution is manufactured, it may often be cheaper for him to make it than to purchase it, especially where a nonrefundable charge is made for the barrel container.

The owner of an orchard of 30 to 40 acres or more, in which lime-sulphur is regularly used for spraying purposes, will find it advisable to consider building a simple plant on his farm for the purpose of preparing his own mixture; or it may be mutually advantageous for two or more fruit growers to unite in the construction of a plant, thus effecting a saving over the cost of purchasing the lime-sulphur concentrate. Community plants built on a still larger scale and operated on a cooperative basis have often proved profitable. For description of plants see pages 11 to 41.

MATERIALS FOR MAKING.

The only raw materials required for the manufacture of lime-sulphur concentrates are lime, sulphur, and water.

LIME.

It is essential to use a high-grade, freshly burned [2] stone lime (CaO), known also as lump lime or quicklime, containing at least 90 per cent of calcium oxid and having as low a magnesium content (preferably not to exceed 5 per cent) as can be secured. The presence of magnesium oxid in the lime is very undesirable, since it forms insoluble compounds, thereby increasing the amount of sediment. Before purchasing lime the fruit grower should ascertain its analysis either from the producer or from the State agricultural experiment station.

[2] Stone lime should also be thoroughly burned, otherwise it will contain carbonates of calcium and magnesium, which will not go into solution.

Different limes behave differently with water, and hence it is often advisable to test a sample before proceeding with the actual cooking operation. This will enable one to ascertain the character of the lime, whether it is quick, medium, or slow in slaking. Limes have been classified by the American Society for Testing Materials as (*a*) quick-slaking, (*b*) medium-slaking, and (*c*) slow-slaking, and it gives the following method for allocating a particular lot: Two or three lumps about the size of a man's fist should be put into a bucket and enough water added barely to cover the lime. If slaking begins in less than 5 minutes the lime is quick-slaking; in from 5 to 30 minutes, medium-slaking; and after 30 minutes, slow-slaking. Slaking is considered to have begun when pieces split off from the lumps or when the lumps begin to crumble. Quick-slaking lime is much to be preferred, since by its use time is saved and there is likewise a greater concentration of heat which aids in the cooking. The use of hot water in slaking the lime, as advocated in this bulletin, will greatly accelerate the action. With slow-slaking lime care should be taken not to use too much water at the start in order to avoid the possibility of drowning the lime. With this type the lime should be placed in a cooker and just enough hot water added to moisten it until there is evidence of slaking, after which additional hot water should be added cautiously from time to time to maintain the action and, at the same time, prevent the mass from burning dry. Medium-slaking lime should be treated in a similar way except that more water may be added without undue danger of drowning the material. When quick-slaking lime is employed the lime may be added to the hot water, a sufficient quantity of the latter being used to cover the lime. During the slaking care should be taken to have a ready supply of additional water on hand to prevent burning.

If preferred high-grade hydrated lime may be substituted for the stone lime, but it will be necessary to use about one-third more of this by weight than is given in the formulas for stone lime. Air-slaked lime should never be used, since this has absorbed carbon dioxid (CO_2) from the air and has thus partly reverted to the original rock or limestone, calcium carbonate ($CaCO_3$).

SULPHUR.

Sulphur has long been recognized as a useful element, and was early employed for medicinal purposes by the ancient Greeks and Romans. At the present time sulphur and its compounds are widely used against insects and plant diseases. It is found upon the market as stick sulphur or brimstone, flowers of sulphur, and commercial ground sulphur, the latter also being known as flour of sulphur. The flowers of sulphur is produced by heating crude sulphur or brimstone until it vaporizes. The vapor is then passed into a cooling chamber, where it is condensed and deposited as a very fine powder on the walls. The commercial, ground material is cheaper than the flowers of sulphur, and if finely pulverized is equally as satisfactory in all respects for the manufacture of lime-sulphur concentrates. It should be about 98 to 99 per cent pure, and this grade is readily obtainable.

CHEMICAL REACTIONS IN THE MAKING OF LIME-SULPHUR CONCENTRATE.

In making lime-sulphur concentrate the first step is to slake the lime (CaO) with water. The union of lime and water produces intense heat and results in the formation of calcium hydroxid ($Ca(OH)_2$). The sulphur is next added, as is also more water, and the entire mass is then thoroughly boiled and agitated until the lime and sulphur have gone into solution. In the course of the boiling several chemical compounds are formed, the more important being calcium pentasulphid (CaS_5) and calcium tetrasulphid (CaS_4), both of which are soluble and are regarded as the most valuable of the lime-sulphur compounds for spray purposes. Another soluble compound, calcium thiosulphate (CaS_2O_3) is also formed, although it is more or less decomposed into free sulphur (S) and calcium sulphite ($CaSO_3$). The latter is insoluble and constitutes the major part of the coarse sediment. As previously mentioned, the magnesium that may be present in the lime forms insoluble compounds, thereby increasing the amount of sediment or "sludge."

FORMULAS FOR MAKING LIME-SULPHUR CONCENTRATE.

In selecting a formula for the making of lime-sulphur concentrate the orchardist will naturally desire to use the one that will produce the best results at the minimum cost. Although it is impossible in the present bulletin to recommend a formula that will best meet the requirements of the individual or community plant, it is hoped that the suggestions given herein will be of value in this connection.

Chemical and field tests have shown that lime and sulphur when boiled in the proper amount of water will go into solution best in the proportion of 1 part of the former to from 2 to 2¼ parts of the latter, provided the chemicals are pure. In most formulas the lime and sulphur are used in the foregoing proportions. Three formulas extensively and successfully used at the present time are here given along with the chief advantages and disadvantages of each.

Formula 1.

Stone lime	pounds	80
Sulphur (commercial ground)	do	160
Water to make finished product	gallons	50

Owing to the relatively large amount of lime and sulphur in comparison with the volume of the finished product, the use of this formula results in a highly concentrated material testing 32° to 34° Baumé. On account of the comparatively small amount of water used, the principal disadvantage of this formula is that there will be some waste of materials by the formation of insoluble compounds, such as calcium sulphite ($CaSO_3$) or uncombined lime and sulphur. If, however, the raw materials are not too expensive, then this loss is not serious, since the cost of labor and fuel in producing a high-test concentrate is no more than in making a product of lower density. By referring to the table of dilutions (p. 11), it will be noted that the high-test concentrate will make more diluted spray solution than a

concentrate of lower density. The high-test concentrate will also require less storage space, which is something of an item if large quantities of spray are needed.

Formula 2.

Stone lime	pounds	50
Sulphur (commercial ground)	do	100
Water to make finished product	gallons	50

This formula is perhaps the most popular among those who make their own solution on the farm, since by its use a reasonably high-test concentrate can be made and, at the same time, the proportion of residue or sediment is not unduly large. In cooking experiments with this formula, the Bureau of Entomology has produced solutions testing from 27° to 28° Baumé.

Formula 3.

Stone lime	pounds	50
Sulphur (commercial ground)	do	100
Water to make finished product	gallons	65

In this formula it will be noted that considerably more water is used, resulting in a less dense finished product. With good materials, however, the resulting concentrate should test from 23° to 24° Baumé. The proportion of sediment is less in this than in Formulas 1 and 2; in other words, a larger proportion of the lime and sulphur go into solution, due to the more complete utilization of the raw materials.

PREPARATION OF LIME-SULPHUR CONCENTRATE.

SOURCES OF HEAT.

As is noted elsewhere, lime-sulphur may be cooked over a wood fire in open vessels, such as an iron caldron or kettle, or it may be made by the use of live steam or steam in closed coils. The method of preparation is essentially the same regardless of the source of heat, although if the cooking is done over a fire or by means of closed steam coils, it will be necessary to add extra water to replace that which is lost through evaporation. In the case of live steam no extra water will be required since there is usually sufficient condensation of the steam during the boiling process to equal the water lost through evaporation.

AGITATION.

During the course of the cooking it is essential to keep the materials well stirred. With small cookers this is usually accomplished by the use of a wooden paddle, while in large plants the stirring is usually done by a mechanical agitator operated by power from a gasoline or steam engine. It is very important to agitate thoroughly, especially during the early stages of the cooking and while the concentrate is being drawn from the cooking tank, to provide an even distribution of the sediment. Agitation is also sometimes secured by the issuance of live steam from perforated steam pipes in the bottom of the cooker (Fig. 14).

MAKING THE CONCENTRATE.

PRELIMINARY STEPS.

As previously stated, the materials needed for the manufacture of lime-sulphur concentrate are lime, sulphur, and water. In order to facilitate the making of the concentrate certain preliminary preparations should be made before the actual process of cooking is begun. The usual procedure is to weigh out accurately the desired amount of sulphur and to mix it with water until it is of a smooth, pasty consistency, taking care to break up all the lumps. This will require considerable time and patience if done by hand, but with the aid of a mixing machine, as shown in Figure 6, the work of making sulphur paste is greatly lessened. If a mixing machine is employed, water may be drawn from the water storage tank, a sufficient amount being used to make a paste that is not too thick to flow freely. Sulphur paste may be conducted from the mixing machine to the cooking tank by means of a trough. Although often desirable, it is not absolutely necessary to make a paste of the sulphur, since the latter may be used in dry form, provided the lumps are first removed by screening. The important consideration is to break up the sulphur lumps as completely as possible. Sulphur should never be dumped into the cooking vessel in large bulk, but should be sprinkled gradually or poured so that a homogeneous mixture will result.

In order to expedite the slaking of the lime, it is desirable to use hot or boiling water. Sufficient water to slake the lime may be heated while the sulphur is being prepared. As described in this bulletin, this is automatically provided for in the larger plants which have a water storage tank heated by either furnace flues or steam coils. Assuming that there is sufficient hot water in the cooking vessel and that the sulphur is free from lumps, the next step is to place the requisite quantity of lime into the cooker and begin the slaking. More water should be added from time to time to prevent burning of the lime. Sulphur should preferably be added when the slaking is well under way or promptly at the conclusion of the slaking. As soon as this has been done, the full quantity of water (preferably hot) should then be added so as to bring the contents up to the volume called for in the formula and an additional amount should be used to equalize that which is expected to be lost through evaporation. If desired, the sulphur may first be placed in the cooking vessel with a little water and the lime added later. After the lime is slaked additional water is added to bring the contents up to the required volume, as described above.

MEASURING GAUGES.

It will be convenient to have a graduated measuring device to enable the operator at any time to ascertain readily the volume of the solution in the cooking vessel, since best results are obtained by not allowing the contents to fall below the volume of the finished product. In small cooking plants an ordinary measuring stick will serve this purpose. This can be made from a wooden strip with notches cut in the edges to indicate the contents. Thus, if a 50-gallon

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batch of the concentrate is to be made over an open fire, it will be well to start with about 60 gallons to allow for the evaporation. The measuring stick in this instance should have at least two notches, one representing 50 gallons, or the volume of the finished product,[3] and the other 60 gallons, or the volume at the start. In the instance of larger plants the cooking tanks can be readily marked or a float gauge installed to indicate the volume.

COOKING.

The cooking is done by actively boiling the lime and sulphur together until they have practically gone into complete solution or, in other words, until the sulphur granules have all dissolved.[4] Abundant experience has shown that this will require about 50 minutes of vigorous and continuous boiling, with a latitude of about 5 minutes either way. Agitation should be thorough throughout the operation, and particularly at the start. Very often the orchardist does not fully appreciate the importance of accurately timing the boiling, and so produces an underboiled or overboiled concentrate. In either case, the amount of sediment is increased. Strict adherence to the proper boiling period is important if the best results are to be obtained and, as previously noted, care should also be taken not to allow the volume of the boiling mass to drop below that given for the finished product.

Care required in making and handling.—During the cooking the mixture should be watched and any sulphur lumps or globules formed should be broken up by means of a paddle. When working over open kettles or vats, care should be taken to protect the eyes from the injurious fumes and sulphur particles that may pass off. For this purpose the operator may wear goggles. Lime-sulphur solution is also very caustic and injurious to the skin so that care should be exercised when handling it. The use of leather gloves well oiled or greased on the inside and outside is advised. If gloves are not worn it is well to protect the hands and wrists with an application of vaseline.

STRAINING THE PRODUCT.

As soon as the cooking has been completed the lime-sulphur concentrate should be drawn off (see also page 24), strained, and run into a settling tank, if one is used, or directly into the storage receptacles. A strainer (brass or tinned iron, *never copper*) of 20 meshes to the inch will remove the coarser particles so that the material passing through will be satisfactory for spraying purposes. Very often, however, a still finer screen, 30 to 50 mesh, is used to remove the finer sediment, or, in some instances, the material is passed through two strainers, the first a 20-mesh to remove the coarser particles, and the second a 30 to 50 mesh. In some commercial and community plants the concentrate is run through a filter press which removes both the fine and coarse sediment.

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[3] Hot liquids contract on cooling, the rate of contraction of water being approximately 4 per cent on cooling from the boiling point to 60° F. Thus it will be found that 50 gallons of lime-sulphur concentrate at the close of the cooking will have a volume of about 48 gallons after it has cooled to 60° F.

[4] To determine when the sulphur granules have gone into solution, dip out some of the material and slowly pour it from one container into another, observing whether or not the granules are present.

CLEANING THE COOKING TANK.

The cooking tank should be cleaned after each cooking by using a liberal supply of hot water and washing out any deposits that adhere to the tank before they cool sufficiently to become hard and caked. By so doing, a better subsequent batch is assured.

SEDIMENT OR SLUDGE.

The coarse sediment is of no use for spraying purposes, but if it should contain considerable uncombined sulphur it may be recooked with the next batch, thereby utilizing that which would otherwise be discarded. However, in well prepared solutions the amount of uncombined sulphur is so small as not to affect to any appreciable extent the subsequent batch. If for any reason the quantity of sludge-sulphur is large and is employed in the next cooking, the effect is merely to produce a higher-test concentrate. The fine siltlike sediment which ordinarily passes through a 20-mesh screen is not objectionable for spraying purposes and need not be removed from the concentrate.

SETTLING TANKS.

In commercial plants a clear concentrate of cherry-red color free from sediment is sometimes obtained by the use of settling tanks into which the material is drawn immediately after boiling. The sediment works to the bottom of the tank, leaving the clear solution above.

TESTING THE CONCENTRATE.

As soon as the lime-sulphur concentrate has cooled the clear solution should be tested with a hydrometer, as described on page 10. The density of the solution should then be recorded or plainly marked on the storage container. Most hydrometers are graduated to test accurately when the solution is at 60° F.

STORING THE CONCENTRATE.

Most orchardists will find that storage of the concentrate in 50-gallon wooden barrels will best meet their requirements. Care should be taken to use only clean barrels free from acids,[5] strong alkalies, or soap, since these materials tend to break down the lime-sulphur. The barrels should be in good condition with hoops well driven, since there will be trouble with leakage unless the barrels are tight. If considerable quantities are stored, as in commercial or community plants, iron tanks are preferable.

In storing lime-sulphur concentrate it should be protected from the air, since exposure causes crystals and a crust formation.[6] The barrels in which it is stored should be completely filled and tightly corked, or, if the concentrate is kept in open containers, a thin layer of medium to heavy oil should be poured on as a protective covering. If the lime-sulphur is to be dipped out of these containers, it will be necessary at first to skim off the oil, but if the

[5] If vinegar barrels are to be used, they must be thoroughly cleaned to remove all traces of acid.

[6] If crystals are formed they may be dissolved in hot water.

container is provided with a valve at the bottom the concentrate can be readily drawn off without disturbing the oil.

Storage temperature.—No special care in storage is necessary, except that it is well not to expose the concentrate to low temperatures on account of the danger of freezing and consequent breaking of the containers. If the lime-sulphur is stored in buildings during the winter, it is not likely to freeze, since a solution testing 32° Baumé does not freeze until the temperature reaches 5° F. A solution of lesser density will freeze at a higher temperature, while one of greater density has a still lower freezing point.

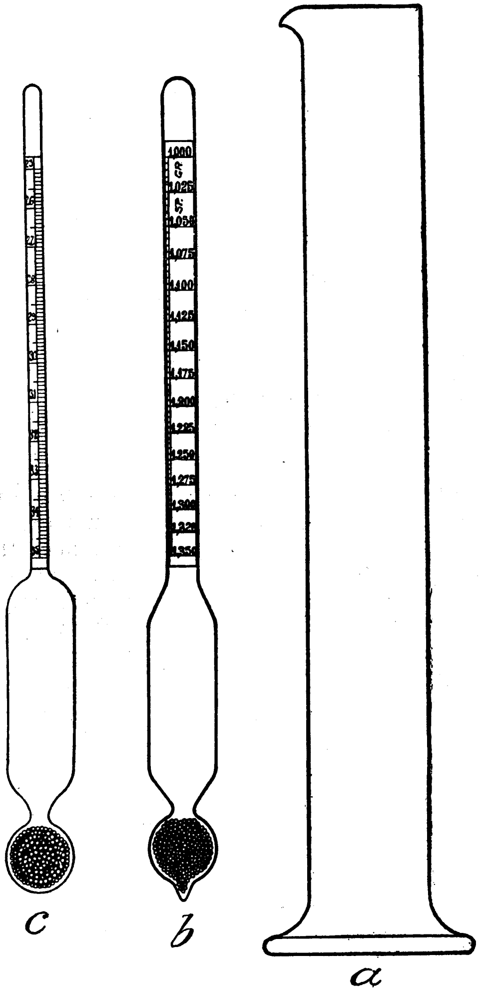

FIG. 2.—Hydrometer outfit for determining specific gravity of lime-sulphur concentrate: *a*, Cylinder for liquid to be tested; *b*, specific gravity spindle; *c*, Baumé spindle. (Quaintance and Siegler.)

Using old lime-sulphur.—Concentrated lime-sulphur is not impaired either by freezing or standing in storage except in so far as it may be converted into crusts or crystals as a result of leakage or undue exposure to the air. (See footnote on p. 9.)

DILUTING FOR SPRAYING PURPOSES.

Hydrometer outfit.—A hydrometer outfit (Fig. 2) consists of a hydrometer and a tall glass cylinder in which the liquid may be tested. Such an outfit is not expensive and may be purchased from dealers in chemical supplies, laboratory apparatus, or orchard supplies. For the testing of lime-sulphur concentrate the instrument should be suitable for testing liquids heavier than water. The hydrometer consists of a glass spindle weighted at the lower end. The upper part of the instrument is provided with a graduated scale on which the density of the solution is indicated. Some instruments are equipped with the specific gravity scale, others have the Baumé scale, and some have both scales. In testing use only the clear liquid which, preferably, should be at a temperature of about 60° F. After the density of the concentrate is known, the proper rate of dilution for

spraying purposes is ascertained by referring to a table of dilutions,[7] as shown in Table 1.

TABLE 1.—*Dilution table for concentrated lime-sulphur solutions.*

Degrees Baumé.	Specific gravity.	Number gallons concentrated lime-sulphur to make 50 gallons spray solution.			Degrees Baumé.	Specific gravity.	Number gallons concentrated lime-sulphur to make 50 gallons spray solution.		
		Summer or foliage strength.	Winter or dormant strength.				Summer or foliage strength.	Winter or dormant strength.	
			San Jose scale.	Blister mite.				San Jose scale.	Blister mite.
36	1.330	1¼	5½	4¾	27	1.229	2	8	6¾
35	1.318	1¼	5¾	5	26	1.218	2	8½	7¼
34	1.306	1½	6	5	25	1.208	2	8¾	7½
33	1.295	1½	6¼	5¼	24	1.198	2¼	9¼	8
32	1.283	1½	6½	5½	23	1.188	2¼	9¾	8¼
31	1.272	1½	6¾	5¾	22	1.179	2¼	10¼	8¾
30	1.261	1¾	7	6	21	1.169	2½	11	9¼
29	1.250	1¾	7¼	6¼	20	1.160	2½	11½	9¾
28	1.239	1¾	7½	6½					

LIME-SULPHUR PLANTS.

SIZE OF PLANTS.

The size of plants depends largely upon requirements and whether the owner intends to make the concentrate only for his own use or also to sell it to his neighbors. Another factor that influences the size of plant is the time when the work will be done. If the concentrate is to be made only as needed, the plant should be large enough to turn out concentrate in sufficient quantity to avoid any interference with the spraying work in the field. On the other hand, if a large storage tank is provided and the solution is properly protected, a smaller plant may be installed, batches made up during slack periods, and time conserved when spraying operations begin. Then, again, there is an advantage in having a stock always on hand for summer spraying and to supply neighbors who may wish to purchase small quantities at times when other work would have to be stopped in order to put the plant in operation.

Lime-sulphur cooking plants may be grouped under two general heads, (1) small orchard plants and (2) large orchard or community plants.

SMALL ORCHARD PLANTS.

Small orchard plants may have capacities as low as 25 gallons of concentrate at a cooking, although 40 to 50 gallons are more usual.

KETTLE PLANTS.

The simplest plant consists of an old-fashioned caldron or kettle such as was once used for soap making or for scalding hogs. The modern form of stock-feed cooker can be adapted to lime-sulphur cooking. If used it is well to surround it with a 6-inch wall of reinforced concrete, except where the door openings occur. If this is

[7] On foliage of sweet cherry use one-third less of the concentrate than that given in the table of dilutions.

not done, the iron jacket surrounding the kettle and stove is likely to rust out rapidly when used for making lime-sulphur concentrate. Wood is used as fuel for cooking in these simple plants.

Figures 3 and 4 show a somewhat improved kettle type of cooker. In these plants the kettle has been permanently set in masonry with

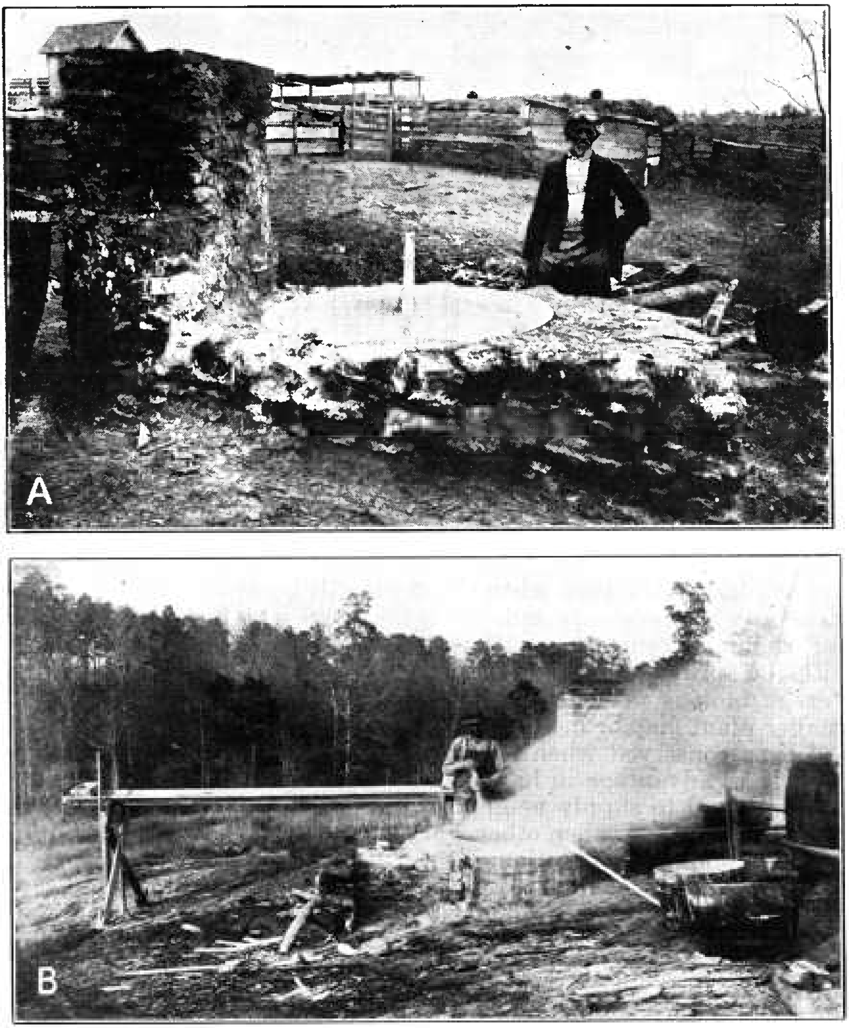

FIG. 3.—Simple types of lime-sulphur cooking plants. These are relatively inexpensive to build and are well adapted to the making of lime-sulphur concentrate in small quantities. In *A*, all materials and the finished product must be lifted by hand; in *B*, the water is piped to the cooker, and the hillside location and trough facilitate straining and filling.

sufficient space for a fire beneath it. Inclosure of the fire decreases the time required to start boiling and assures more even cooking. The plant shown as *B*, Figure 3, has advantages over the plant indicated as *A*, in that water is piped to the cooker and there is a trough so situated that filling of either barrels or spray tank is facilitated.

The portable strainer box resting upon the end of the trough is held directly under the low end during filling and thus catches and removes the coarser sediment. The undesirable features of such plants are the necessity for dipping out the finished product and their more or less limited capacity.

FURNACE-COOKING PLANTS

Figure 5 shows a simple orchard plant built in a hillside and arranged so that the finished product may be drained by gravity, stored near by, and later run into the spray tank or containers, which may be filled by gravity directly from the storage barrels. The elevation of the storage barrels shown in Figure 5 necessitates the use of a hand pump. This might be eliminated if the topography permitted drawing and straining directly into the barrels. One hundred and fifty gallons at a cooking can be handled conveniently with a plant of this type. If the upper tank for heating water for a subsequent batch is provided, the time interval between cooking is materially reduced.

FIG. 4.—A simple form of lime-sulphur cooking plant similar to those shown in Figure 3 but with practically triple the capacity. Three kettles afford means for continuous operation, one being used for heating water and the others for cooking the concentrate. An undesirable feature is that the finished product must be dipped out.

Figure 6 shows a popular type of farm plant in which wood is used as fuel. Figures 7, 8, and 9 show, in plan and elevation, the details of the plant and Figures 10 and 11 show two arrangements of all equipment and indicate the sequence of operations in connection with this single-cooker furnace-type plant. In Figure 10 a level location is assumed with driveways leading to door openings *A*, *B*, and *C*. Figure 11 shows the same plant arranged for either hillside or level ground location. In this plant there are two tanks, one for heating

water preparatory to making a batch of concentrate, and the other for cooking the solution. The water tank is located at the rear of the cooking tank with its bottom higher than the elevation of the mixture in the cooking tank. This allows better control of the hot water supply. Directly under the cooking tank is a brick furnace fitted with a grate having an ash pit below. The flue from the combustion chamber to the smoke pipe is carried under and in contact with the bottom of the water heating tank so that while one batch is cooking,

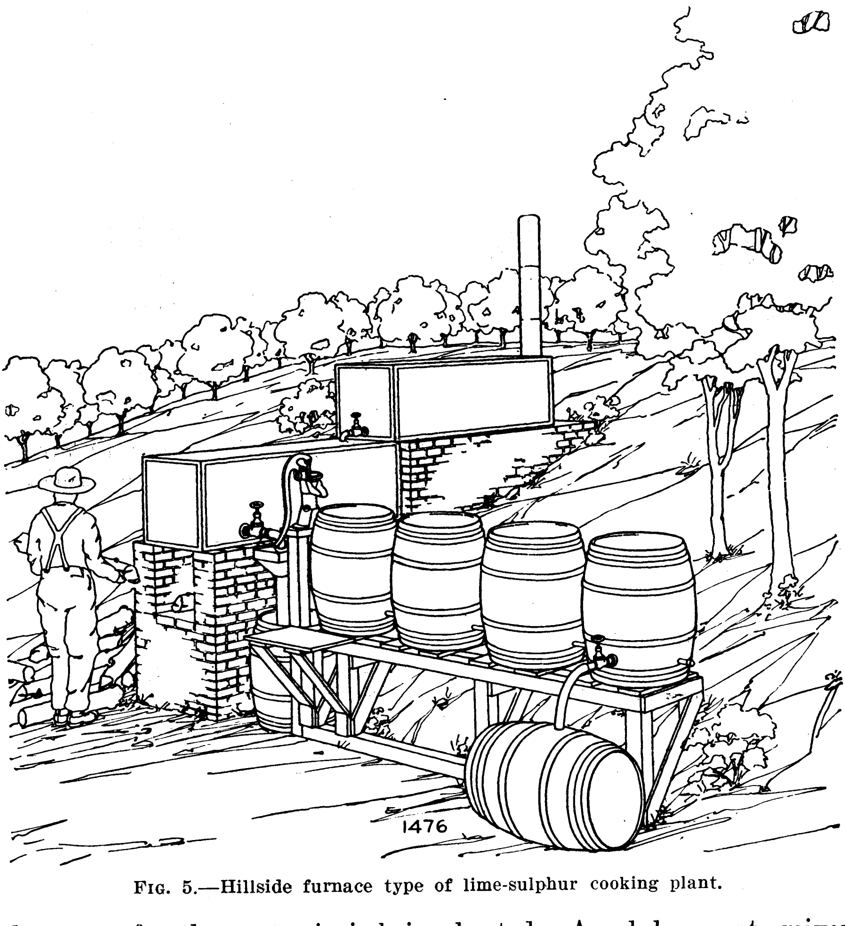

FIG. 5.—Hillside furnace type of lime-sulphur cooking plant.

the water for the next mix is being heated. A sulphur paste mixer consisting of a barrel mounted on bearings is supported on a frame above the platform. The barrel can be filled through an opening in its side and revolved either by hand or motor power so as thoroughly to mix the sulphur paste. If the barrel is in a fixed position a portable trough is used to lead the paste from the barrel into the cooking tank. The cooking vat is fitted with a revolving agitator described on page 40 which is mounted on a steel shaft extending through the tank and wall and fitted with a pulley. The agitator is revolved by means of a belt and gasoline engine. Two outlets are provided in the front end of the cooking tank, one located so that

the bottom of the hole is 3 inches from the bottom of the tank and the other in the bottom as near the end as possible. The bottom outlet is used in thoroughly cleaning the tank. The concentrate is drawn off through the upper outlet into a filter tank alongside of the furnace. The filter tank is fitted with three removable strainer boxes which remove the heavy sediment or sludge. These strainer boxes may be of any convenient size and should have bottoms of brass or tinned iron wire, 30 to 50 meshes to the inch. The use of 3 boxes permits a more rapid flow of solution. The boxes may be slid along in rotation under the outlet pipe so that as soon as the one directly under the outlet contains an appreciable deposit of sludge it may be pushed along to the end position, removed, and emptied. Meantime the next box has come into position without interrupting the flow. The cleaned box is then replaced in the first position. Barrels are filled from the filter tank, a short piece of rubber hose being used to direct the flow. Old automobile inner tubes serve the purpose.

A small gasoline engine of $1\frac{1}{2}$ to $2\frac{1}{2}$ horsepower will drive the agitator, but if motor power is not available the stirring may be done by hand with a long-handled wooden hoe.

The operation of this plant, if arranged as in Figure 10, is as follows: The materials are delivered in wagon lots at door A and are stored in bins as indicated. The size of the storage bins will depend upon the quantity of the materials to be purchased at one time. In some of the smaller plants storage space is not provided, lime and sulphur being purchased only as needed and used, but the availability of storage space may mean a saving in time and expense since the materials may then be hauled in as return loads in advance of the spraying season and thus be on hand when needed.

When operation commences, sulphur and lime are taken from bins as indicated by lines *D–F*, and *E–G*, and weighed on scales located conveniently to the working platform. After weighing the materials are raised to the working platform, the sulphur being carried to the mixer, line *I–J*, while the lime goes directly to the cooking tank as indicated by line *K–L*. Hot water, line *T*, for slaking the lime is drawn from the hot water tank while that required for making the sulphur paste is supplied from the same source by bucket or hose, along line *N*. The sulphur paste is run into the cooking tank as indicated by line *O*. The cooked concentrate is drawn off by line *Q* and run into the filter tank from which the strained solution is drawn as indicated by line *R* and barreled or by means of a long hose connection supplied directly by gravity or pump to a spray tank backed up to door *C*. Line *S* indicates the course of concentrate intended for immediate use while the course of that barreled and stored for future delivery to trucks or wagons through door *B* is as indicated. Lines *U* and *V*, terminating at *W*, show the convenient disposal point for the sludge and waste. Fuel would be brought in through door *X*. This arrangement provides for the movement of materials up one side of the building, through the cooking and straining apparatus, and down the other side, thus avoiding all interference between operations. The floor space required, not including any for raw materials or finished product, is approximately 24 by 26 feet.

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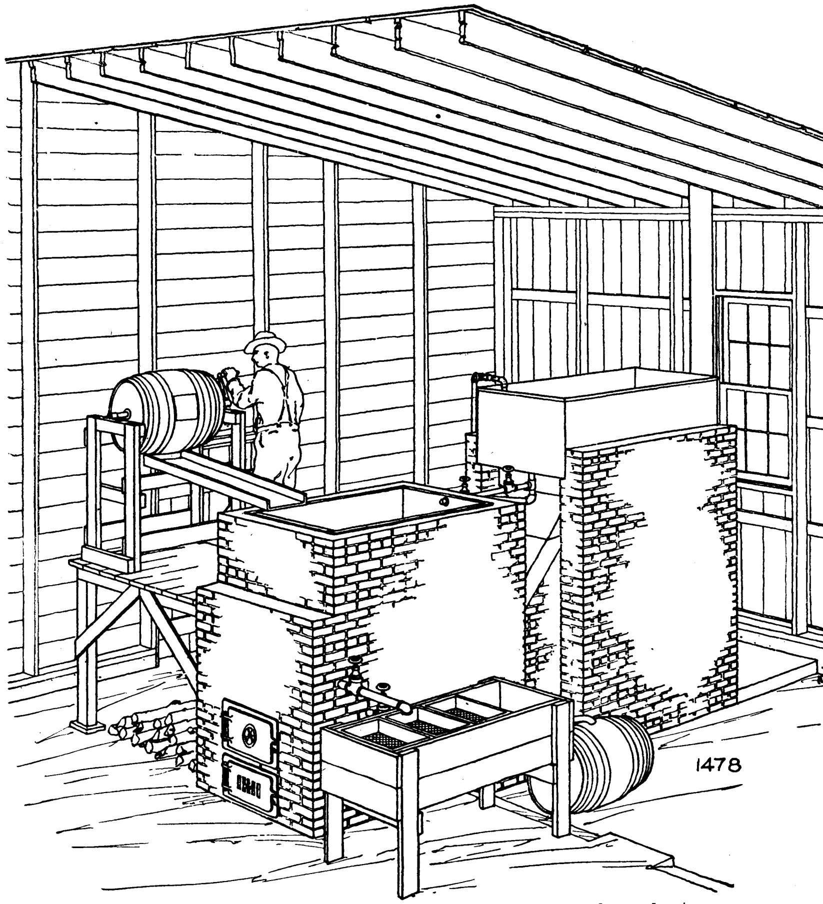


FIG. 6.—Single-cooker furnace type of lime-sulphur plant.

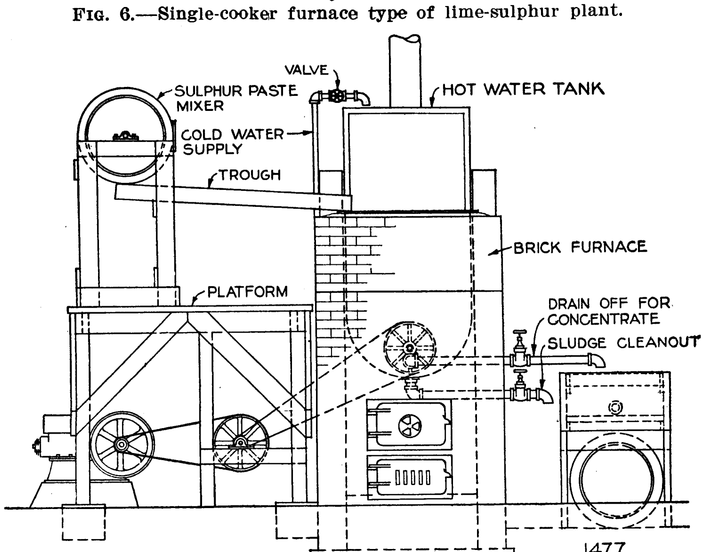


FIG. 7.—End view of single-cooker furnace type of lime-sulphur plant.

In a plant arranged as shown in Figure 11 the materials are delivered at and stored in the bins. From the bins they are carried to the scales and weighed, and thence to the sulphur mixer and cooking

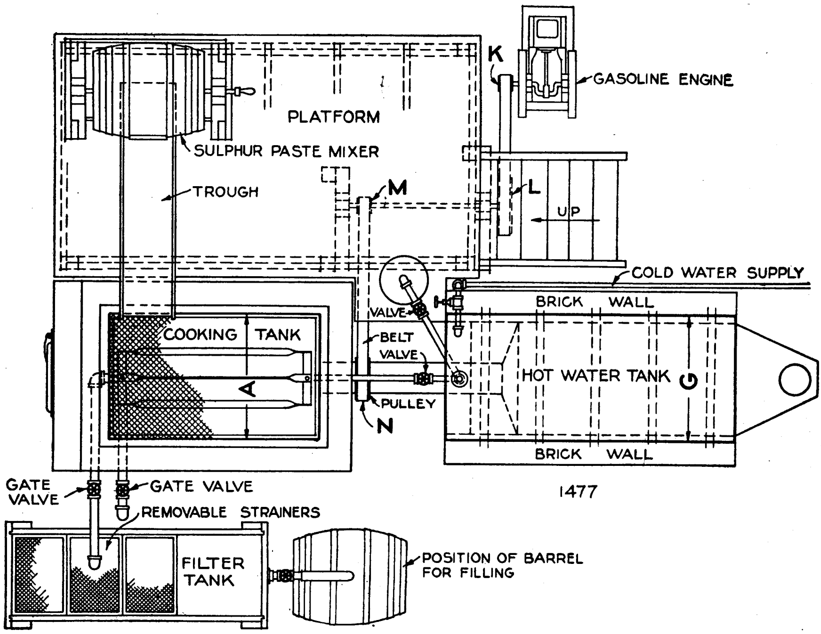


Fig. 8.—Plan of single-cooker furnace type of lime-sulphur plant.

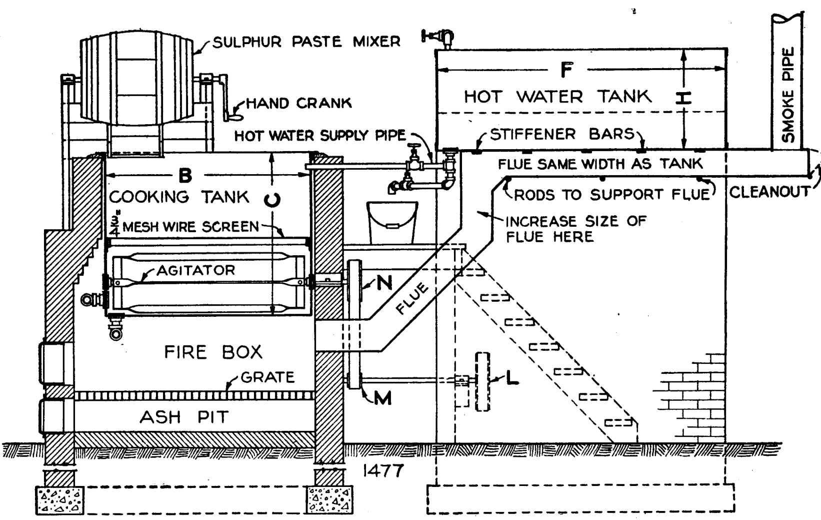


Fig. 9.—Sectional view of single-cooker furnace type of lime-sulphur plant.

tank. If the site is on a hillside, and the storage floor is at or near the level of the working platform, the materials may be handled to better advantage. The working platform may be extended to the wall of the storage room, the scales being placed on the platform or,

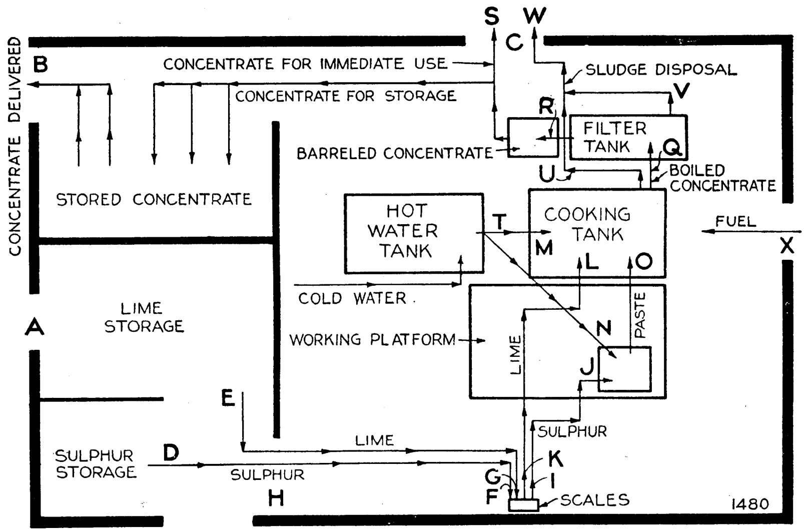


FIG. 10.—Routing diagram for single-cooker furnace type of lime-sulphur plant.

if the levels are slightly different, the scales may be placed in the storage room and a runway erected between the storage room and platform. The boiled product is drawn off, strained, and barreled or piped as in the arrangement illustrated in Figure 10. Thus storage and immediate delivery of the barreled product are provided for at one end of the building instead of at separate points as in Figure 10. All routing is indicated by marked lines with arrows. The floor space required, not including any for raw materials or the offset space marked stored concentrate, is approximately 25 by 24 feet. Additional concentrate storage may be had by extending the small shed as required.

Dimensions, capacity, and detailed data for this plant (Figs. 6, 7, 8, and 9) are given in Tables 2 and 3.

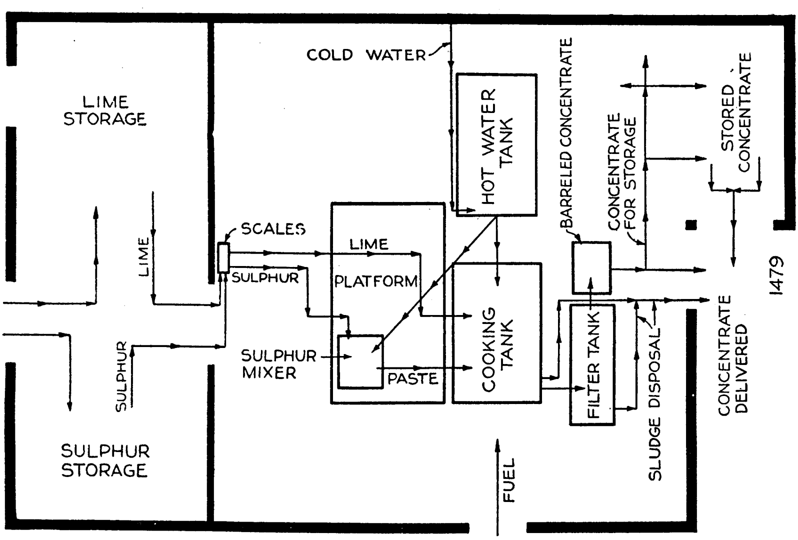


FIG. 11.—Alternate routing diagram for single-cooker furnace type of lime-sulphur plant.

TABLE 2.—*Furnace and steam plants for lime-sulphur.*

Capacity of plant, each cooking: Gallons.	Capacity of plant, each cooking: Barrels, 50 gallons.	Cooking tank: Dimensions (see Fig. 12): A	Cooking tank: Dimensions: B	Cooking tank: Dimensions: C	Cooking tank: Dimensions: D	Cooking tank: Dimensions: E	Cooking tank: Gross volume.	Water-heating tank, Rectangular: Length F.	Water-heating tank, Rectangular: Width G.	Water-heating tank, Rectangular: Depth H.	Water-heating tank, Rectangular: Gross volume.	Agitator (each tank), Arms (cast-iron pulleys): Number.	Agitator, Arms: Diameter.	Agitator, Arms: Width.	Agitator, Shaft: Diameter.	Agitator, Shaft: Length.	Agitator, Paddles: Number.	Agitator, Paddles: Size.	Agitator: Center agitator shaft from bottom tank.	Supports under water tank: Number.	Supports under water tank: Spacing.	Supports under water tank: Description.	Agitator drive, Gasoline engine: Horsepower.	Agitator drive, Gasoline engine: Revolutions per minute.	Agitator drive, Diameter of pulleys: K	Agitator drive, Diameter of pulleys: L	Agitator drive, Diameter of pulleys: M	Agitator drive, Diameter of pulleys: N
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
		Ins.	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Cu. ft.*	*Ins.*	*Ins.*	*Ins.*	*Cu. ft.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ft. in.*		*Ins.*	*Ins.*									
150	3	24	48	48	36	12	30	84	24	24	28	2	10	2	$1\frac{1}{4}$	5 4	4	$\frac{3}{8}$ by $2\frac{1}{2}$	6	5	(*a*)	(*b*)	$1\frac{1}{2}$–$2\frac{1}{2}$	550	4	12	4	12
300	6	36	60	48	30	18	55	84	36	30	52	2	15	2	$1\frac{1}{4}$	6 4	4	$\frac{1}{2}$ by $2\frac{1}{2}$	$8\frac{1}{2}$	5	(*a*)	(*b*)	$1\frac{1}{2}$–$2\frac{1}{2}$	500	4	12	4	10
400	8	48	72	48	24	24	86	84	48	30	70	3	20	2	$1\frac{1}{2}$	7 4	4	$\frac{1}{2}$ by $2\frac{1}{2}$	11	5	(*a*)	(*b*)	$1\frac{1}{2}$–$2\frac{1}{2}$	450	6	12	4	15
600	12	36	*c*60	*c*48	*c*30	18	110	84	54	42	110	2	15	2	$1\frac{1}{2}$	6 4	4	$\frac{1}{2}$ by $2\frac{1}{2}$	$8\frac{1}{2}$	5	(*a*)	(*b*)	$2\frac{1}{2}$–5	400	6	12	4	12
800	16	48	*c*72	*c*48	*c*24	24	172	84	66	48	154	3	20	2	$1\frac{1}{2}$	7 4	4	$\frac{1}{2}$ by $2\frac{1}{2}$	11	5	(*a*)	(*b*)	$2\frac{1}{2}$–5	350	8	12	4	15

a Equal.
b 3-inch I beams or old iron strong enough to support tank and resist sagging.
c Two tanks.

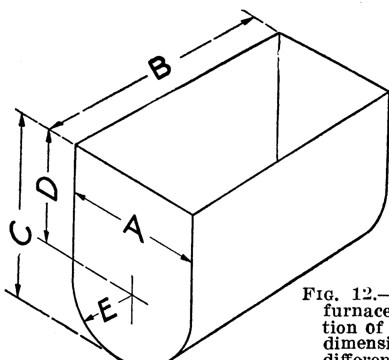


FIG. 12.—Diagram of cooking tank for furnace and steam plants for preparation of lime-sulphur concentrate. (For dimensions of tanks for plants of different capacities, see Table 2, Columns 3 to 7.)

TABLE 3.—*Brick furnace plants.*

Capacity of plant.	Space requirements, not including storage space for materials or concentrate.			Ash pit.			Furnace.			Flue dimensions.		Smoke pipe.
	Length.	Width.	Height.	Length.	Width.	Height to underside grate.	Length.	Width.	Height grate to tank.	At breeching.	Under water tank.	
	1	2	3	4	5	6	7	8	9	10	11	12
Galls.	*Feet.*	*Feet.*	*Feet.*	*Ft. In.*	*Ft. In.*	*In.*	*Ft. In.*	*Ft. In.*	*In.*	*In.*	*In.*	*In.*
150	24	22	12	4 9	2 1	9	4 9	2 1	21	9 by 9	20 by 7	9
300	26	24	12	5 9	3 1	9	5 9	3 1	21	9 by 9	32 by 7	9
400	28	26	12	6 9	4 1	9	6 9	4 1	21	10 by 10	44 by 10	10
600	25	20	19	5 9	3 1	9	5 9	3 1	21	10 by 10	48 by 10	10
800	26	23	20	6 9	4 1	9	6 9	4 1	21	10 by 10	58 by 10	11

STEAM-COOKING PLANTS.

Steam is preferable to a wood fire in cooking lime-sulphur concentrate as it affords better control of the heat, but it is doubtful whether it would be economical to install a steam-cooking plant having a capacity of less than 400 gallons per cooking.

Steam may be introduced into the mixture through either a perforated or a closed pipe coil placed in the cooking tank and slightly above the bottom. It is generally preferable to cook by live steam admitted through a perforated pipe, since in cooking there is a cer-

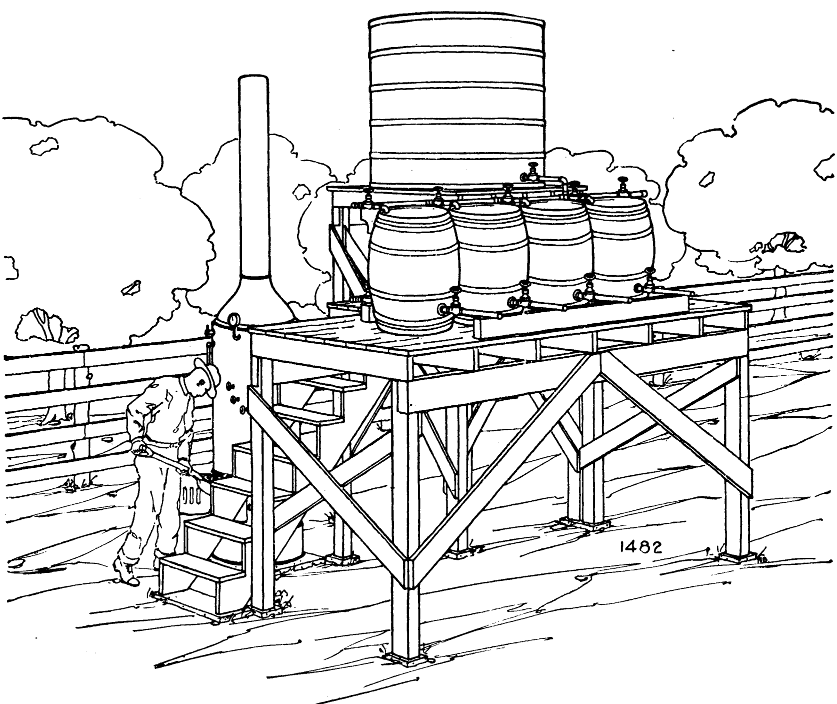
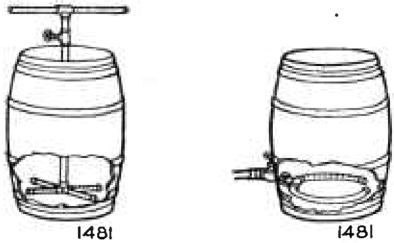


FIG. 13.—Outdoor steam-cooking plant for preparation of lime-sulphur concentrate.

tain loss due to evaporation, and the live steam not only serves to keep the liquid at the boiling point but supplies the necessary "make-up" at the same temperature. If a closed coil is used, much more pipe is required in the cooking tank.

Inexpensive steam lime-sulphur orchard cooking plants are quite common and exist in a variety of forms. Figure 13 shows an inexpensive and usual arrangement involving the use of a steam boiler. Two forms of steam jet pipes for an installation of this type are shown in Figure 14. The type shown in *B* is preferable because there is no piping in the upper part of the barrel to interfere with hand stirring or agitation. In some plants of this type the outlets of the several barrels are connected into one main pipe (Fig. 15) running along the front. Separate outlets are preferable to avoid clogging of the main pipe with sludge.



A *B*

FIG. 14.—Two forms of steam jet pipes for cooking lime-sulphur in barrels. The steam connection for *B* is preferable to that of *A*.

Figure 16 shows another orchard plant of this type. The condition of this plant indicates frequent boiling over of the concentrate with a consequent loss which in the aggregate is quite appreciable. With plants of this type the concentrate must be dipped out of the barrels, a procedure that should be avoided if possible. A platform, as shown in Figures 13 and 15, high enough to permit filling the spray tank directly from the boiling vessel adds greatly to the efficient operation

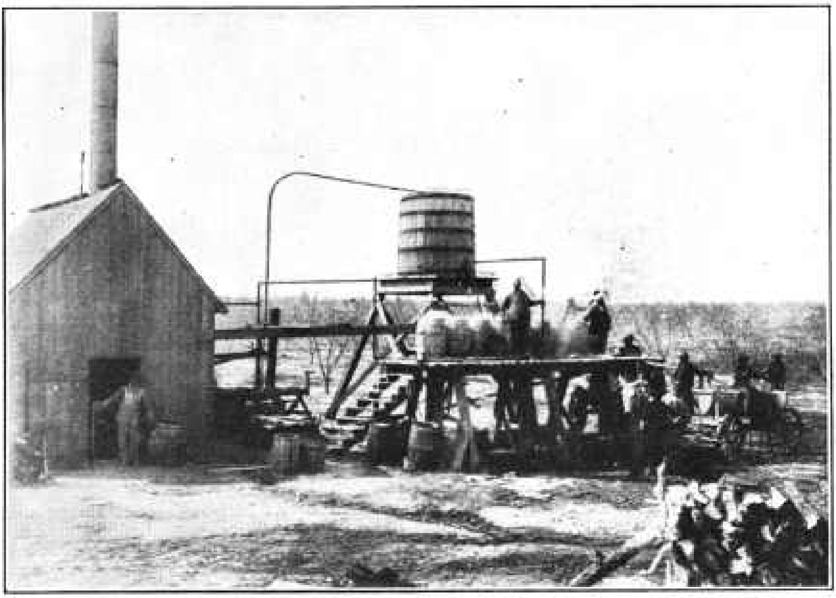


FIG. 15.—This lime-sulphur cooking plant is of the type shown in Figure 13. The boiling must be carefully watched but otherwise it is a very good arrangmeent. It differs from the plant shown in Figure 13 chiefly in that the barrels all empty into one main line with an outlet at the end of the platform.

FIG. 16.—With this steam-cooking lime-sulphur plant the waste due to boiling over and dipping out may be quite appreciable and makes undesirable working conditions under foot.

of the plant. Figures 17 and 18 show other examples of temporary or makeshift steam-cooking plants. They serve, in a way, the purpose for which they are intended, but are not to be recommended.

FIG. 17.—It is undesirable to use lime-sulphur cooking vessels of different sizes. Such an arrangement necessitates the weighing of different amounts of materials for each container.

The arrangement of a simple, permanent, home-built plant which has been in service several years is shown in Figure 19. In this plant there are two units, each consisting of two tanks which may be built of concrete, wood, or metal. One tank of each unit is equipped with steam jets for cooking the mixture. When it has boiled sufficiently, the solution is dipped out of the cooking tank and poured into the adjoining tank, where it is diluted with the proper proportion of water. Agitation during cooking and stirring during dilution are done with a long-handled wooden paddle. As soon as the boiled concentrate is diluted and thoroughly mixed with water, it is drawn from the bottom of the tank through a pipe line and delivered at a convenient point for filling the spray tank. Each cooking tank

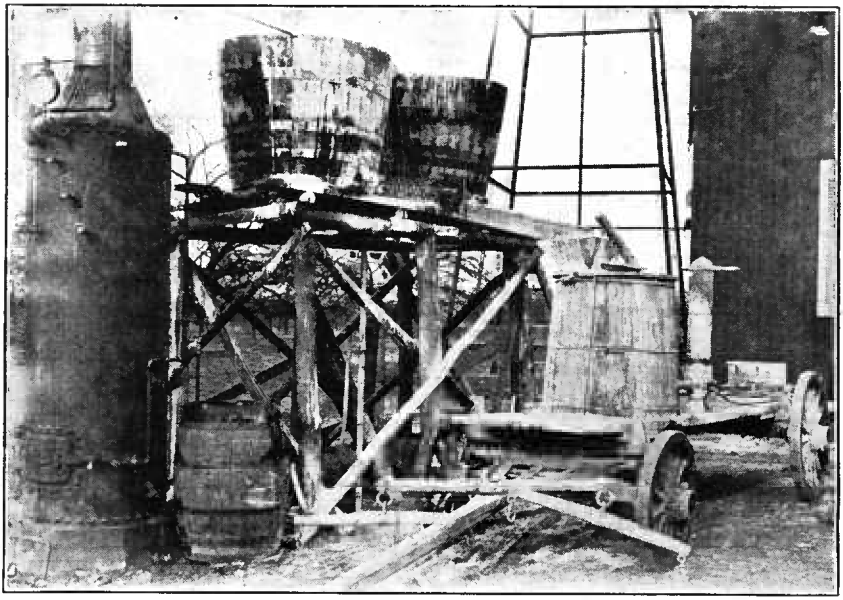


Fig. 18.—A lime-sulphur cooking plant somewhat similar to that shown in Figure 17. With this arrangement, however, it is unnecessary to dip out the finished product by hand.

is provided with a sludge outlet which is plugged during the cooking process. Water is supplied under pressure from a storage tank on top of a hill back of the plant. The water line runs along the floor in front of the tanks with valved outlets into each tank and a connection for supplying water to the boiler. A portable or stationary boiler may be used. The steam line properly supported is carried overhead with valve-controlled drops to the steam jets. A wooden shed with open front and an extended roof protects stored lime and sulphur from the weather. If the cooking tank is made not larger than about 36 inches square by 40 inches deep, one man at the tanks may be able to make concentrate fast enough to supply two spray-tank wagons. This outlay does not include a convenient means for straining the concentrate, nor does it contemplate preparation except as needed for immediate use. It requires a hillside location.

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The layout of a somewhat more elaborate home-built steam-cooking plant is shown in Figure 20. This might properly be called a concrete lime-sulphur plant, although parts of it could as well have been built of wood or metal and, like the one just described, requires a hillside location. Its arrangement, however, includes a storage tank beneath the working floor. It is thus possible to prepare concentrate during spare time. The driveway directly in front of the lower side of the house permits filling the spray tank directly from the outlet pipe. Rain water from the roof of a near-by barn is stored in a tank located at an elevation higher than the cooking tank and is

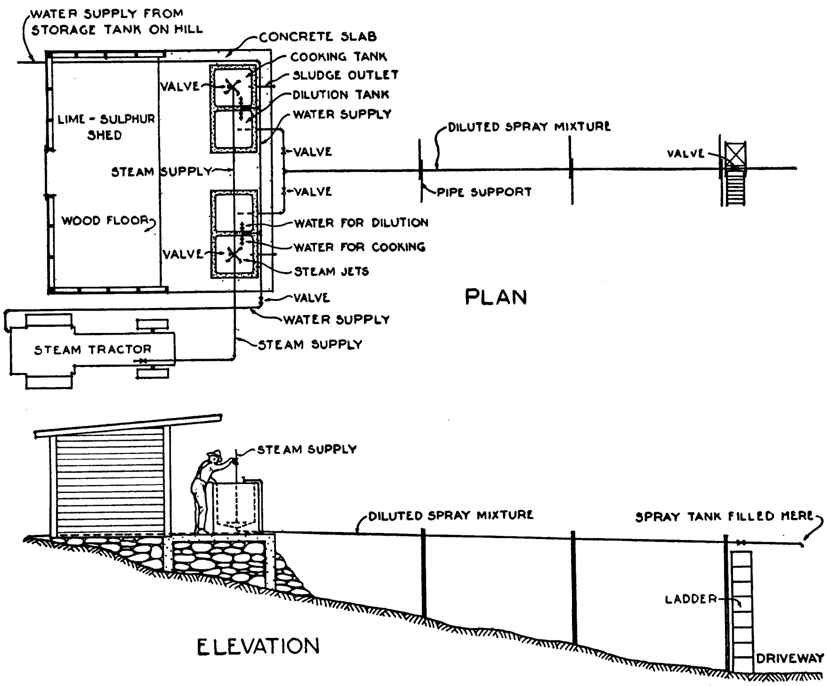

FIG. 19.—A simple, permanent, home-built lime-sulphur steam-cooking plant which has been in service for several years.

the source of the water supply. Steam for cooking is supplied by a boiler permanently placed in the cooking house and is introduced into a mixture through steam jets. When cooking is completed the solution is drawn off from the bottom of the cooking tank into the bottom of a filter tank adjoining it and is strained upwards through removable screens that rest upon a ledge just below the bottom of the outlet pipe that conveys the filtered solution into the storage tank. A hose connection is provided so that the lime may be slaked in a portable slaking box before it is introduced into the cooking tank. Sludge is removed through a pipe in the bottom of the filter tank, which extends through the side of the building. The concentrate is diluted in the spray tank and if water supply stations are provided at several points in the orchard, the weight that must be hauled from the plant is materially reduced.

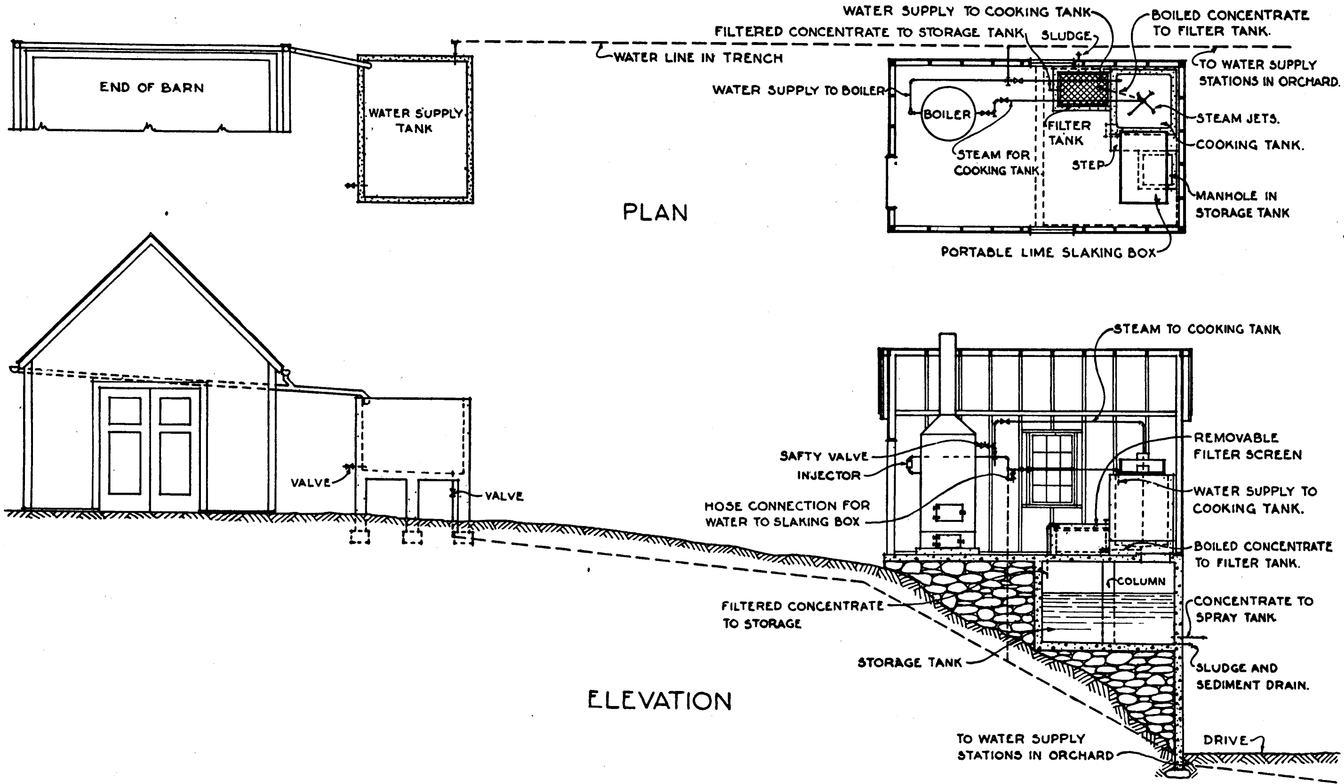

FIG. 20.—A somewhat more elaborate home-built, steam-cooking lime-sulphur plant than that shown in Figure 19.

In Figure 21 is shown a plant similar to that illustrated in Figure 6 except that steam is used for cooking instead of a wood fire under

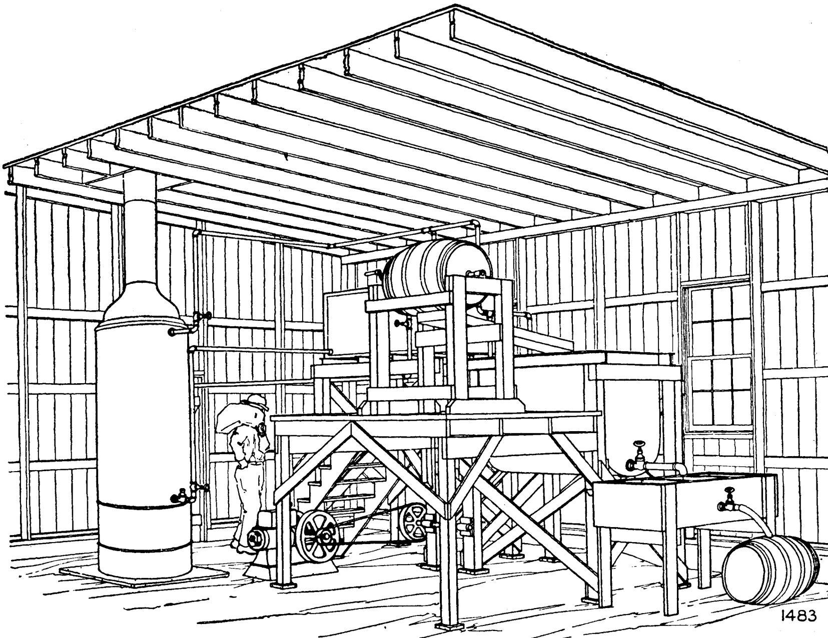

FIG. 21.—Single-cooker steam type of lime-sulphur plant.

the tank. The time required for raising the temperature of the water from 60° to 180° F. depends upon the length, size, and kind of pipe

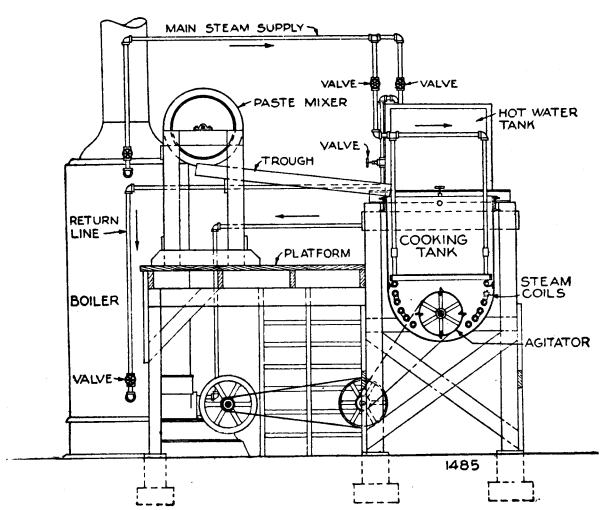

FIG. 22.—End view of lime-sulphur cooking plant shown in Figure 21.

or tubing used in the steam coils and the temperature of the steam, which in turn depends upon its pressure. The data given in Table 4 for the steam coils of this plant are based on the heating of the

amount of water necessary for one batch in 40 minutes with steam at 5 pounds per square-inch pressure. If steam is used at higher pressure both the quantity of pipe and the time required for water

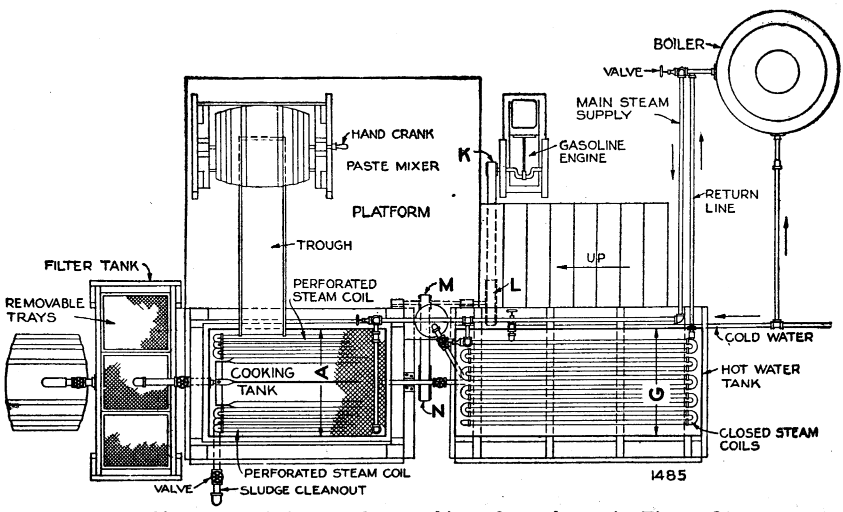

FIG. 23.—Plan of lime-sulphur cooking plant shown in Figure 21.

heating will differ from that given above and in Table 4.[8] This design is based on the use of iron pipe, and the linear feet of pipe installed in the water tank should not be less than as given under

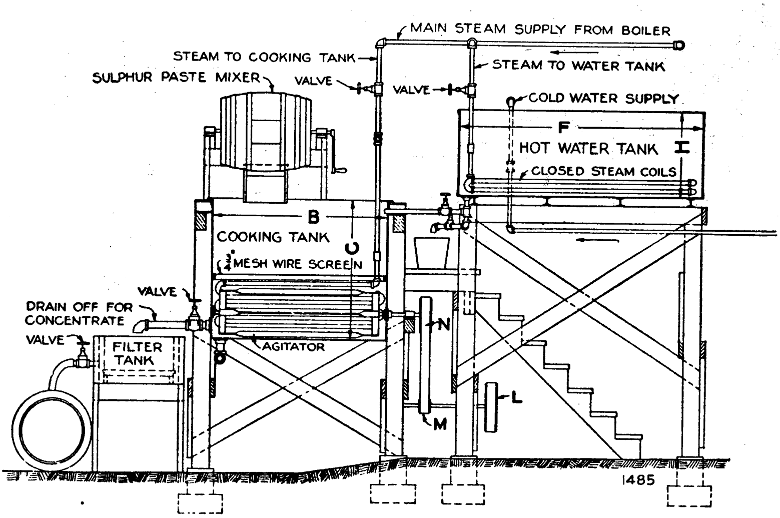

FIG. 24.—Sectional view of lime-sulphur cooking plant shown in Figure 21.

columns 5 to 8 of Table 4. The length of pipe in the cooking tank should be such as to assure the introduction of sufficient live steam to heat the mixture uniformly. Figures 22, 23 and 24 show

[8] Upon request the Division of Agricultural Engineering, Bureau of Public Roads, United States Department of Agriculture, will advise concerning this point in connection with particular installations.

this plant in plan and elevations. Dimension data for plants of 150, 300, and 400 gallons capacity are given in Tables 2 and 4. The piping in the cooking tank is perforated with $\frac{3}{16}$ to $\frac{1}{4}$ inch holes spaced 6 inches apart but not in line so that when the steam is admitted into the coils it will enter the mixture at different angles and so be uniformly distributed.

TABLE 4.—*Steam plants for lime-sulphur.*

Capacity of plant (gallons).	Space requirements, not including storage space for materials or concentrate.			Pipe required in water tank.				Recommended boiler capacity (horsepower).[a]
	Length.	Width.	Height.	Area.	Linear feet for— 1-inch.	1¼-inch.	1½-inch.	
1	2	3	4	5	6	7	8	9
	Feet.	*Feet.*	*Feet.*	*Square feet.*				
150	23	18	12	18	51	40	35	18
300	25	20	13	35	102	80	70	35
400	27	22	13	46	133	106	92	46
600	26	30	14	73	212	168	146	72
800	27	33	14	102	296	235	205	100

[a] Based on steam at 5 pounds per square inch pressure.

Figures 25 and 26 show two arrangements of all equipment and indicate the sequence of operations in connection with the single-cooker steam-type plant. In the arrangement illustrated in Figure 25 materials are delivered at the indicated door and stored in bins. Lines beginning at the storage room indicate the course of material from

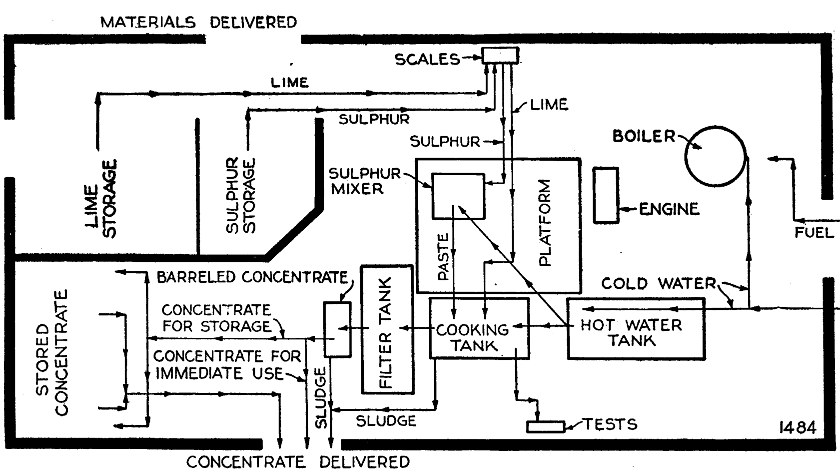

FIG. 25.—Routing diagram for single-cooker steam type of lime-sulphur plant.

the bins to the scales. From this point they are delivered into the cooking tank as in the plant shown in Figures 10 and 11. The passage of the concentrate through the filter tank is as indicated by the lines and arrows. The delivery door is located conveniently for loading the barreled product or piping the strained material directly into the spray tank. The floor space re-

quired, not including any for raw materials or finished product, is approximately 20 by 28 feet. Figure 26 shows an alternate arrangement of the same plant requiring a floor space approximately 20 by 27 feet. The routing of the operation, as in the layouts illustrated in preceding figures, is indicated by lines and arrows.

LARGE ORCHARD OR COMMUNITY PLANTS.

Community plants, that is, those supplying concentrate to a number of orchards and those capable of meeting the requirements of large individual growers, are of greater capacity than the installations previously described. Two designs for plants of larger capacity are shown in Figures 27 to 30 and 33 to 36, both inclusive.

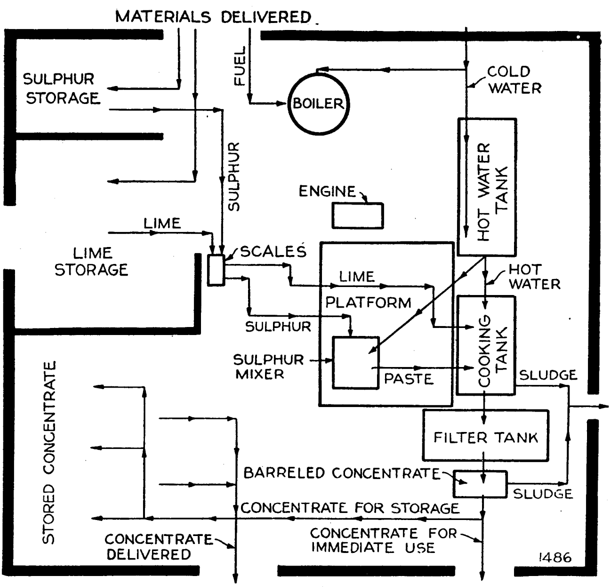

FIG. 26.—Alternate routing diagram for single-cooker steam type of lime-sulphur plant.

Figures 27, 28, 29 and 30 show a furnace-type plant so designed that either cooker can be operated separately or both may be run at the same time, or, if the work is properly laid out and managed, practically continuous operation can be secured with the same crew required for a single-cooker plant. Dimension data for plants of 600 and 800 gallons capacity are given in Tables 2, 3, and 4.

For continuous operation it is necessary that a program or schedule of operations be followed so that none of the work connected with one batch will interfere with any operation in connection with the other tank. A schedule that will afford practically continuous operation for five hours is given in Table 5. During this time four batches can be prepared and handled. A boiling period of 50 minutes allows time for the preparation of a subsequent batch. Precaution must be taken, however, not to introduce the second batch too soon. It should be introduced 5 minutes before the first batch has finished cooking in order that the third and fourth batches may be prepared and cooked as indicated in the schedule (Table 5).

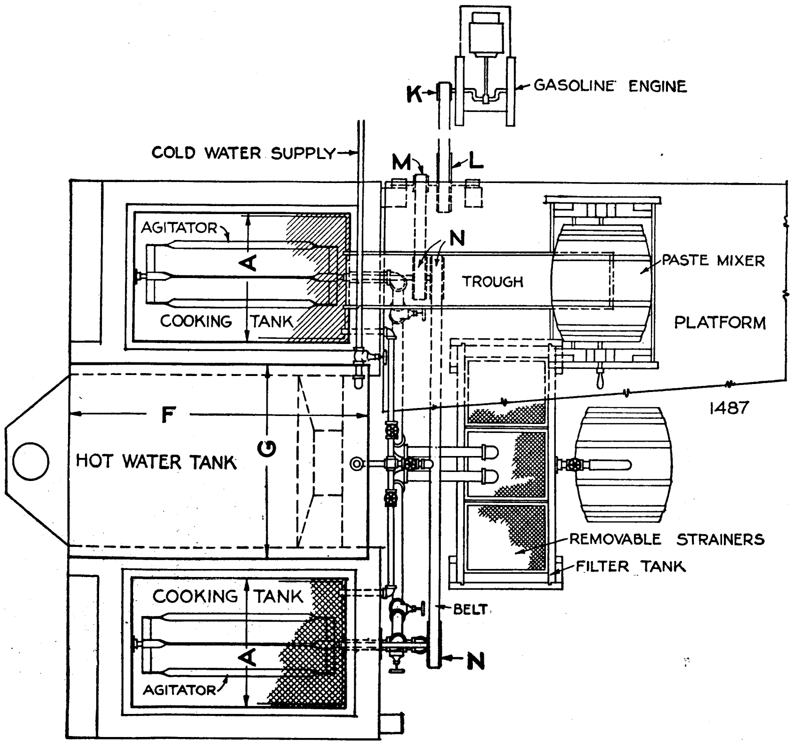

FIG. 27.—Plan of double-cooker furnace type of lime-sulphur plant.

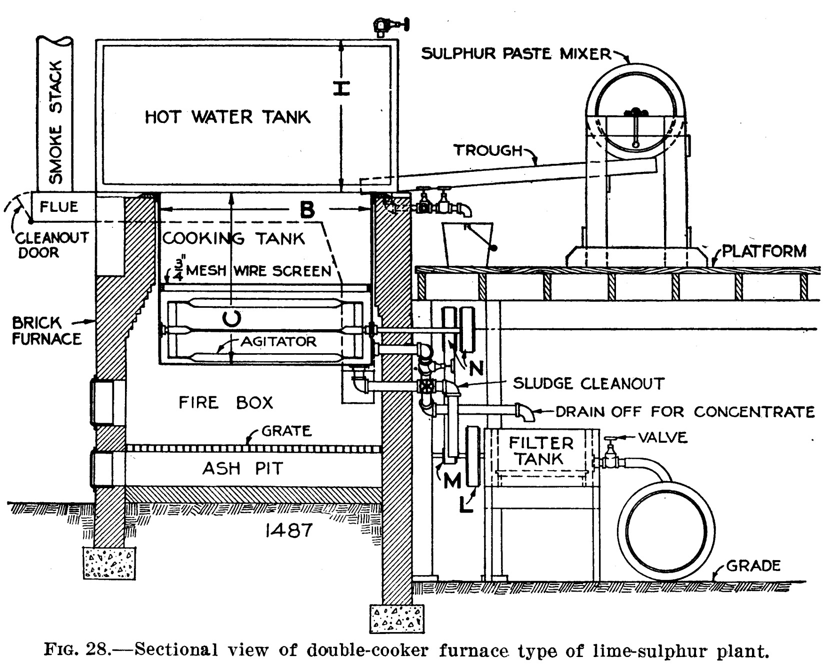

FIG. 28.—Sectional view of double-cooker furnace type of lime-sulphur plant.

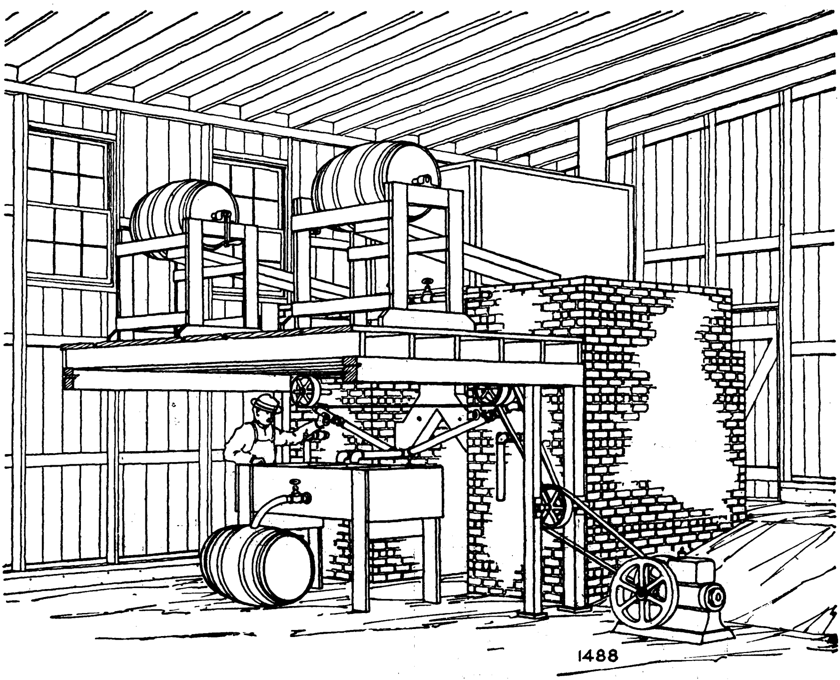

FIG. 29.—Double-cooker furnace type of lime-sulphur plant.

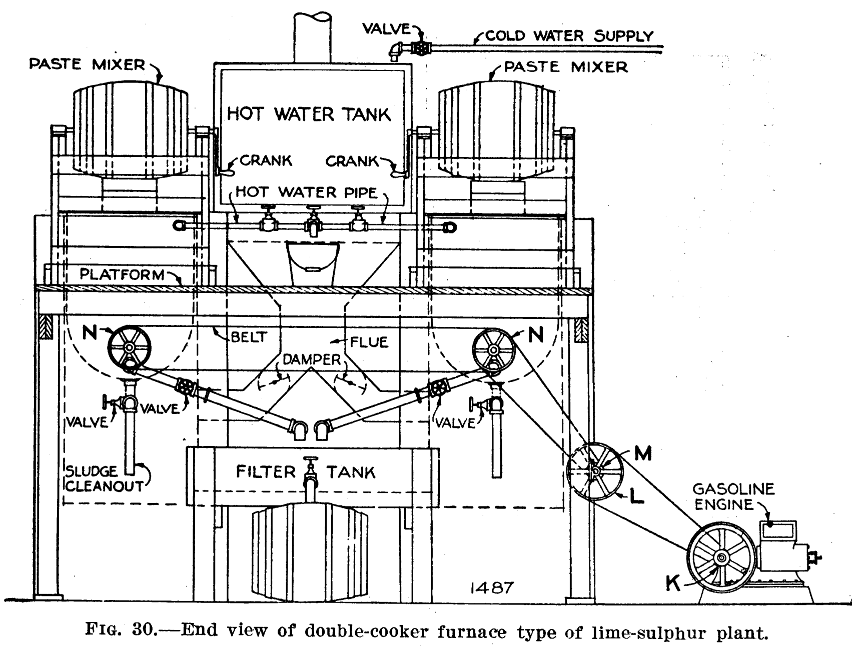

FIG. 30.—End view of double-cooker furnace type of lime-sulphur plant.

TABLE 5.—*Program for operating a double-cooker lime-sulphur plant with one group of workers.*

Batch No. 1.		Batch No. 2.		Batch No. 3.		Batch No. 4.	
Time.	In tank No. 1.	Time.	In tank No. 2.	Time.	In tank No. 1.	Time.	In tank No. 2.
7.00	Prepare materials for batch.						
7.15	Introduce into tank; bring to boiling; prepare to draw off.						
7.30	Begin boiling period.	7.30	Preparations for drawing off.				
		7.45	Prepare materials for batch.				
		8.00	Spare time.				
		8.15	Introduce into tank; bring to boiling.				
8.20	Draw off and barrel.						
		8.30	Begin boiling period.				
8.35	Clean tank.						
8.50				8.50	Prepare materials for batch.		
				9.05	Introduce into tank; prepare to draw off.		
		9.20	Draw off and barrel.	9.20	Begin boiling period.		
		9.35	Clean tank.				
		9.50				9.50	Prepare materials for batch.
						10.05	Introduce into tank; bring to boiling.
				10.10	Draw off and barrel.		
						10.20	Begin boiling period.
				10.25	Clean tank.		
						10.35	
				10.40			
						10.50	Prepare for draining off.
						11.10	Draw off and barrel.
						11.25	Clean tank.
						11.40	General clean-up; prepare for afternoon work.
						12.00	

It is likely that different owners will find it advisable to make changes in the suggested program because of the difference in the efficiency of the workers. This is to be expected, but care must be taken not to start the cooking of a batch at such a time that it can not be handled promptly when it is ready. It might be found advisable, when operating a plant in this manner, to have one man act as supervisor so as to avoid delay, duplication of effort, or interference with operations. If the contents of each tank are to be cooked at the same time and consequently drawn at the same time, more workers will be required, and it might be possible to reduce the periods other than the cooking period enough to permit preparation of six instead of four batches during 5 hours' operation.

Figures 31 and 32 explain the arrangement, operation, and routing of the large orchard or community double-cooker furnace-type plant shown in Figures 27 to 30. In this layout a side-hill location is assumed with delivery of the raw materials at the uphill door, as indicated in Figure 31, which is a plan at a level above the working platform. Figure 32 shows the arrangement and routing below the platform level and hence does not show the raw material storage space.

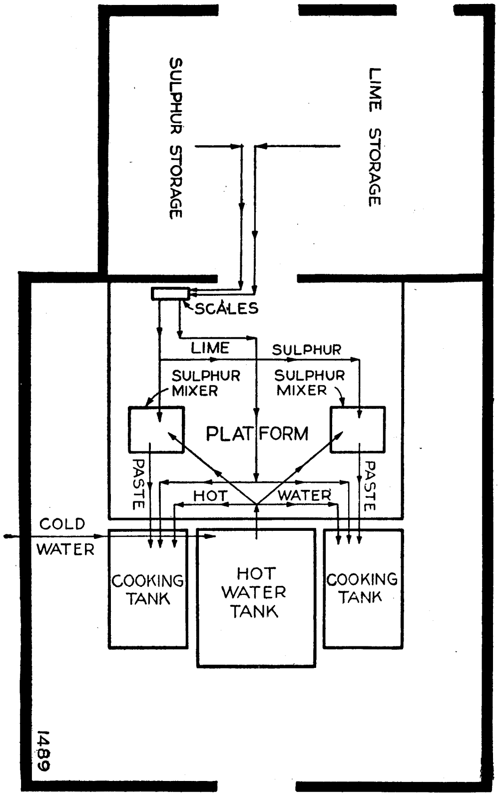

Fig. 31.—Routing diagram for double-cooker furnace type of lime-sulphur plant at upper level.

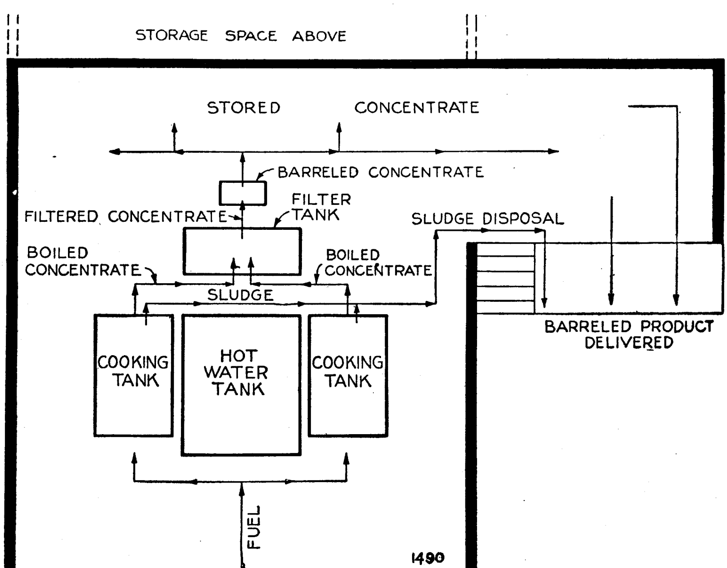

Fig. 32.—Routing diagram for double-cooker furnace type of lime-sulphur plant at lower level.

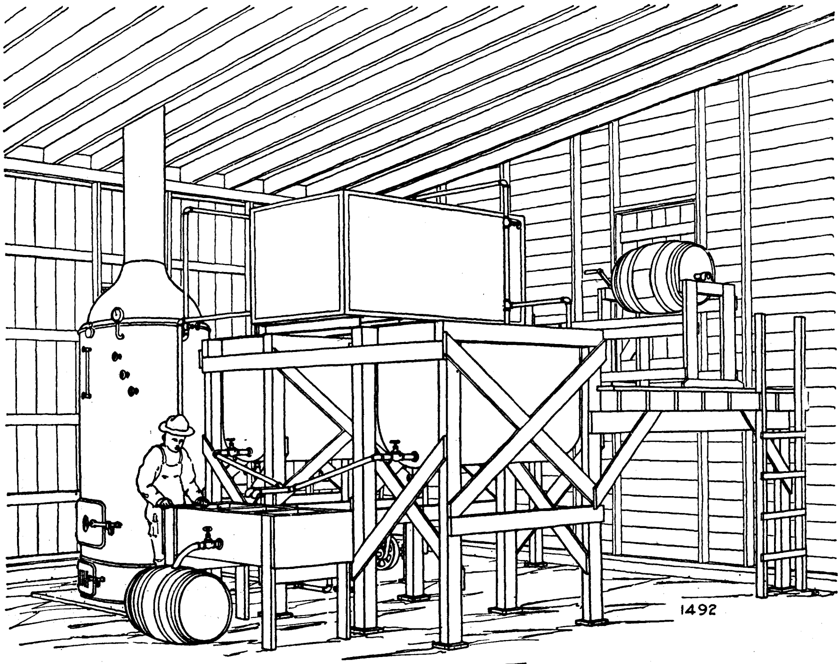

FIG. 33.—Double-cooker steam type of lime-sulphur plant.

Figure 31 may be superimposed over Figure 32, the wall back of the space for stored concentrate in Figure 32 coinciding with the dividing wall in Figure 31. As the floor level of the storage space corresponds to that of the working platform, the materials may be conveyed to

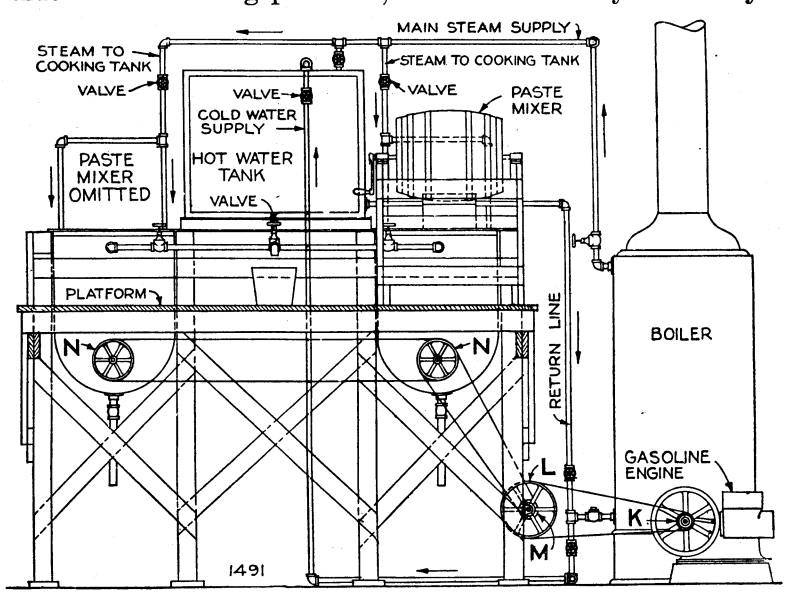

FIG. 34.—End view of double-cooker steam type of lime-sulphur plant.

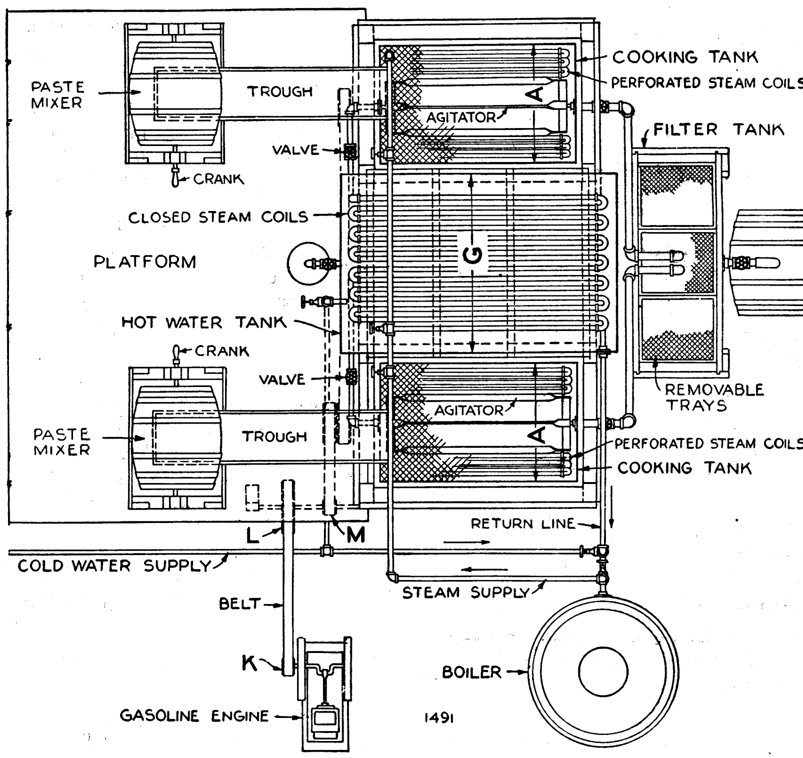

FIG. 35.—Plan of double-cooker steam type of lime-sulphur plant.

the cooking tanks and mixers without having to be elevated by hand. The drawing-off, barreling, etc., is done at the lower level directly under the working platform as indicated by the marked lines and

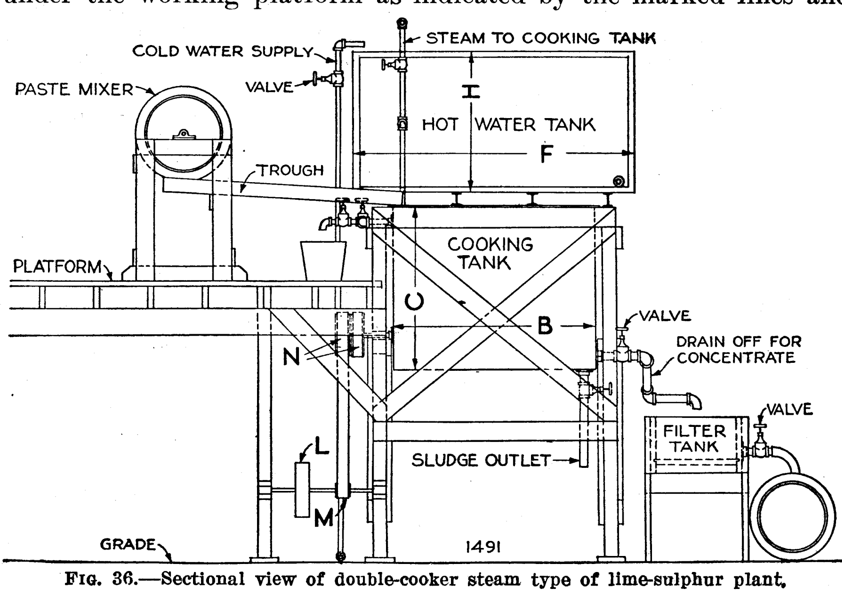

FIG. 36.—Sectional view of double-cooker steam type of lime-sulphur plant.

arrows. If a hillside location is not available the same routing diagram will apply, but the materials will have to be lifted to the working platform. The space required, not including that for storage of materials or finished product except that under the platform, is approximately 23 by 26 feet.

A steam double-cooker plant is shown in Figures 33 to 36, inclusive. Dimension data for plants of 600 and 800 gallons capacity are given in Tables 2 and 4. Sizes and lengths of pipes for transmitting heat are based on steam pressure at 5 pounds per square inch and provide sufficient surface to heat the water from 60° to 180° F. in 40 minutes and to bring the mixture to the boiling point in 15 minutes. It is

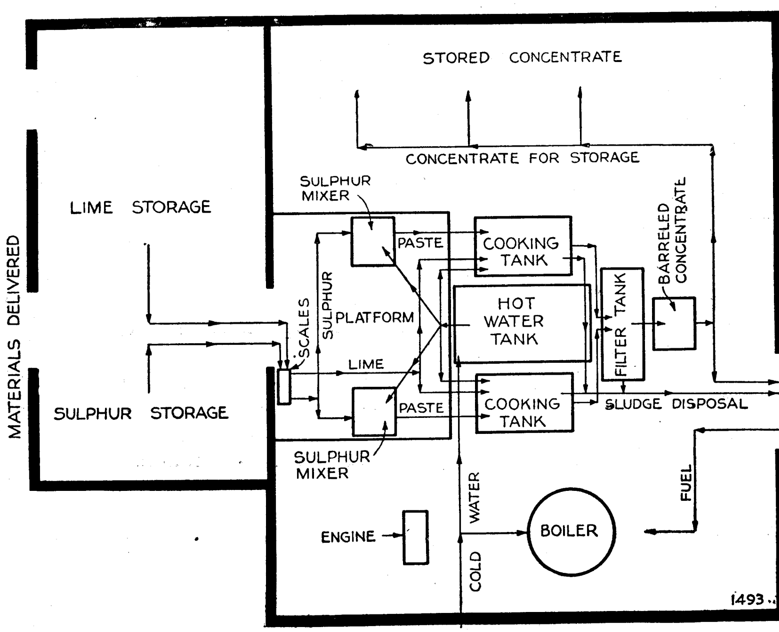

FIG. 37.—Routing diagram for double-cooker steam type of lime-sulphur plant.

assumed that water under pressure sufficient to force it into the boiler is available. When this is not the case a feed pump or injector must be used. The size and capacity of pump required depend upon the conditions.[9]

Figure 37 shows an arrangement of the community or large orchard double-cooker steam plant illustrated in Figures 33 to 36 inclusive, and located on a level site. The routing differs from that shown in Figures 31 and 32 in that the finished product is handled from the opposite end of the cooking tank, the movement of the materials through the plant being as indicated by lines and arrows. The space required, not including that for storage, is approximately 24 by 26 feet.

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[9] Upon request the Division of Agricultural Engineering, Bureau of Public Roads, United States Department of Agriculture, will advise concerning this point in connection with particular installations.

CHARACTERISTICS OF EQUIPMENT.

COOKING TANK.

Cooking tanks are built of wood, iron, or steel, or they may be of concrete.

Wooden tanks are suitable only when steam is used for cooking, although there are instances of wooden tanks with iron bottoms that extend far enough up the sides to protect the wooden part from damage through direct contact with the open fire. Wooden tanks have one advantage over those of metal in that, wood being a poor conductor of heat, boiling will probably occur more quickly in a wooden tank than in a metal tank of equal capacity and surface. Wood tanks should be made of material not less than 1½ inches thick. Tongued and grooved material is preferable because of the tight seams that can be made. It is advisable to strip the seams and to fill all joints with white lead paste so as to minimize the danger of leakage.

Sheet or galvanized iron tanks should be of material not less than $\frac{1}{16}$ inch thick and if the under side is to be in direct contact with fire a greater thickness is recommended. Tanks of cylindrical, cubical, or oblong shape can often be obtained through local orchard supply houses or hardware dealers. The type shown in Figures 8, 9, 21, and 23 will probably have to be specially built, but since the round bottom has a decided advantage over the flat bottom it is considered a good investment.

Concrete cooking tanks are in use in small lime-sulphur installations. Those that have been inspected by the authors seem to show no ill effects, but no investigation has been made to determine definitely the desirability of using concrete for this purpose. Figure 19 is a diagrammatic layout of a plant in which the cooking and dilution tanks are of concrete. This particular plant has been in service several years. The plant illustrated in Figure 20, with the exception of the walls and roof of the house, is constructed entirely of concrete. If concrete is used for this purpose, it is advisable to employ a comparatively rich mixture, not leaner than 1:2:4 mix, and to use no aggregate larger than ½ inch. The walls and bottom of the tank should be reinforced in both directions in order to provide against cracks due to temperature variations. During cooking the upper part of the walls will be cool as compared to the lower part and bottom. A thickness of not less than 6 inches is advised.

Cooking tanks should have two outlets, one in the end nearest the filter tank and so placed that the bottom of the opening will be 3 inches above the bottom of the tank and the other in the bottom as near as possible to the upper outlet. The upper outlet is used in withdrawing the concentrate, while the bottom outlet is used in completely draining and cleaning the tank with hot water after each cooking. Neither opening should be less than 2½ inches in diameter and each should be equipped with either a gate or quick-opening valve. A globe valve should not be used.

The capacity of the cooking tank should be one and one-half times the volume of the mixture to be cooked, otherwise there is a likelihood of the solution boiling over and producting a dirty and sloppy condition about the plant. In Table 2, columns 8 and 12, are given

the gross volumes of tanks recommended for the respective batch volumes given in column 1. These volumes include the extra space allowed for boiling.

The cooking tanks of most farm plants are not provided with covers. Although the temperature of the solution may be raised to the boiling point more quickly in a covered tank, the use of this type of tank is of doubtful advantage. Practically all commercial cooking is done in uncovered tanks. If covers are employed they should be made of metal or wood and should fit loosely over and rest upon the top edge of the cooking tank. They should be supported from above by ropes or light steel wire cables passing over pulleys to a counterweight so that they may be raised and lowered readily. Several holes should be provided in the top to permit steam and gases to pass off.

Cooking tanks may be cylindrical, cubical, or oblong in shape with either flat or round bottom. The rectangular tank is usually easier to install and the round bottom can be cleaned with less difficulty than can a flat bottom with square corners. Moreover, the rounded shape of the bottom insures thorough mixing of the entire mass with an agitator like that shown in Figures 9 and 24.

On the inside of the cooking tank, just above the agitator, supports should be provided for a three-fourths-inch mesh heavy wire screen. This screen prevents the lime and sulphur coming in contact with the agitator until the lime is properly slaked. If the screen is not provided lumps of lime may clog the agitator and, in the furnace type, become burned through contact with the bottom of the tank before it is slaked.

HOT-WATER TANK.

The hot water tank may be built of either metal or wood if the water is heated by steam. If the hot gases of the smoke flue of a furnace are utilized in heating the water a metal tank with flat bottom is necessary. Concrete tanks may be employed where steam is used for heating. The capacity should be sufficiently greater than the volume required for one cooking that there will be ample hot water available for cleaning the cooking tank or tanks after a cooking and for the next batch. Sizes and volumes of tanks suitable for plants of various capacities and like those shown in Figures 6 and 21 are given in columns 3 to 12 in Table 2. Metal water tanks should be of material not less than one-twentieth of an inch thick. If the tanks are elevated, as in the designs illustrated, the bottoms should be reinforced with iron bars, old rails, channels, or other suitable metal supports.

The water tank may be filled from a cold water supply pipe fixed in position over the tank or from a hose line. Discharge from the tank should be out of the bottom through a $1\frac{1}{4}$ or $1\frac{1}{2}$ inch pipe, preferably the larger size. The discharge line should be equipped with two outlets, one to the cooking tank and the other for drawing hot water for use in the sulphur-paste mixer. Each outlet should be controlled by means of a cut-off valve or cock. A measuring stick or gauge graduated so as to read gallons and parts of gallons according to the height of water in the tank will assist materially in drawing off a given quantity. The gauge may be portable or it may be permanently fixed on the inside of the tank.

STORAGE TANKS.

Storage tanks for the cold water and for the prepared concentrate may be of concrete, wood, or metal.

The water-supply tank may be above, level with, or below the ground surface. The elevated tank has the advantage of gravity drainage, but on the other hand it requires that substantial supports be provided. Cylindrical wooden tanks are often used for the water supply. These are usually elevated and supported on wooden posts. Elevated concrete tanks require properly designed walls or reinforced columns, the number and size depending upon the capacity and dimensions of the tank. The tank, too, should be reinforced and the walls should have a minimum thickness of 6 inches.

Storage tanks for concentrate are frequently built of concrete. They are usually placed below ground so that they may be supplied from the filter tank by gravity. Concrete underground storage tanks are used because they are comparatively easy to construct. The bottom and walls should be poured at one time so that there will be no joint through which leakage might occur. Such tanks, especially if of large size, should be reinforced to prevent cracks due to settlement or earth pressures. The top may be of concrete or of wood. The floor of the house of the plant shown in Figure 20 forms the top of the storage tank, access to the inside being through a manhole. Concrete work of this kind requires careful design and placement of the reinforcement, and provision must be made for additional support for superimposed loads such as the cooking and filter tank in Figure 20.

FURNACE AND FLUE.

Brick is perhaps the best material of which to construct the furnace, which should be equipped with a cast-iron grate and cast-iron fire and ash-pit doors. The use of fire and ash-pit doors is, of course, not absolutely necessary, but they afford far better regulation of the fire and make for more efficient operation. If the air supply necessary to combustion is controlled, economy in fuel consumption is possible. The top of the grate should be about 15 inches below the lowest part of the bottom of the cooking tank, and the ash pit should have a depth of about 9 inches. It is well to extend the furnace about 12 inches beyond the front end of the cooking vat. This aids cooking by bringing the fire nearer the front end so that the entire length of the vat is subjected to the greatest heat of the fire. The furnace construction should be practically air tight to assure a good draft. Lime mortar may be used in laying the brick and in bedding the cooking tank, but cement mortar is preferable.

If the hot gases of the smoke flue are to be utilized in heating the water, as in Figures 9 and 28, the flue should be run under the water tank, and at this point should be as wide as the tank and not less than 6 inches deep. It should be built of not less than 20-gauge galvanized iron and should be covered with insulating material to prevent or lessen the radiation of heat. The top of the flue should be omitted under the water tank so as to reduce the amount of metal between the gases and the water as much as possible. All wood surfaces that are less than 12 inches from the smoke pipe or flue should be protected with insulating material.

An air-tight cleanout door should be installed at the junction of the flue and the smoke pipe. Care should be taken when connecting the flue with the furnace to see that all joints are air-tight. In plants of the double-cooker furnace type two flues, entering the same smoke pipe, are required and an air-tight damper should be installed in each flue, near the smoke pipe, so that only one furnace can be used, if desired, without draft interference from the other connection.

The diameter of the smoke pipe should be 9 inches, 10 inches, and 11 inches in plants of 150 to 300 gallons, 400 to 600 gallons, and 800 gallons, respectively. The pipe should be rigidly supported and high enough to provide a good draft. It should be equipped with a damper placed in a convenient position.

AGITATORS.

Agitation is considered absolutely necessary, both during cooking and while the concentrate is being drawn from the cooking tank. There is always a tendency of the suspended matter to settle and to form a more or less thick deposit in the bottom of the tank. This should be kept continually in motion, by hand or mechanical means, in order to insure a product of even quality and a minimum amount of sludge. This is especially necessary during the first half of the cooking period.

Agitators vary in design according to the shape and type of tank in which they are to be used. The type shown in Figures 9 and 24 is extremely simple in design. It consists of two or three cast-iron spiders (old pulleys may be used) and four pieces of flat iron. The spiders are mounted on a shaft running longitudinally through the cooking tank. The flat iron paddles are connected to each spider and should be twisted so that, as the agitator revolves, they will cut through the heavy mass at an angle and, in disturbing it, tend to raise it into the less dense portion of the mixture. Suggested sizes of parts for agitators of this type are given in Table 2. There should be a clearance of 1 to 1½ inches between the bottom of the tank and the agitator paddles when in their lowest position.

If a circular cooking tank is used the shaft of the agitator should be installed in a vertical position and the agitator should be of a different design. A suitable one consists of a shaft of square iron to which are bolted several pieces of flat bar iron as paddles. These should be bent slightly and the leading edge sharpened so as to cut the mass at an angle as the shaft revolves.

The agitator should make about 60 revolutions per minute. The speed of a horizontal agitator will be governed by the speed of the engine that drives it, the diameter of the pulley on the engine shaft, and the diameter of the large pulley on the end of the agitator shaft, all of which must be correctly proportioned. If a vertical shaft agitator is used the shaft must be extended far enough upwards through a plank bolted to the top of the tank to allow for the necessary gearing. A bevel gear fitted to the shaft, the pinion engaging it and fitted to the end of a jack shaft, and a large pulley on the other end of the jack shaft must all be correctly proportioned to give the required speed of the paddles.

Power for the agitator may be obtained from a 1½ to 5 horsepower gasoline engine, depending upon the size of the plant, or from a

small steam engine if steam is used for cooking. If the concentrate is prepared during slack periods the spray-pump engine may be used.

ENGINE AND PULLEY SIZES.

A $1\frac{1}{2}$-horsepower engine will drive the agitator in the smaller plants, while $2\frac{1}{2}$ to 5 horsepower engines will be needed for the larger plants. The size of the pulleys necessary to obtain 60 revolutions of the agitator per minute will depend upon the speed of the engine. In Table 2 under columns 26 to 29 recommended sizes of pulleys for five different engine speeds are given. The sizes of pulley *K*, Figure 8, are those usually found on engines operating at the speeds indicated. If the speed and size of pulley *K* are other than as given in Table 2, then the sizes of pulleys, *L*, *M*, and *N* must be changed accordingly in order to cause the agitator shaft to turn at 60 revolutions per minute.

ARRANGEMENT AND LOCATION.

Temporary or makeshift lime-sulphur cooking plants are sometimes located in the open without shelter for the plant or workers. A shelter, which need not be elaborate or expensive, is an economy in the end as protection from the weather prolongs the life of the equipment, especially that of a steam boiler or an engine, and makes it possible to operate the plant at any time. It is necessary at least to protect the stored supply of lime and sulphur.

If the plant is housed all openings should be of liberal size in order that light and ventilation shall be ample and that fuel, materials, and finished product may be handled easily.

The arrangement of the plant should be planned with a view to labor and time saving. A hillside location, such that the raw materials may be delivered readily at or slightly above the level of the working platform, is very desirable especially if there is available a gravity water supply which will deliver, without pumping, to the water tank and boiler. Such a plant might be termed a gravity installation, since the direction of practically every movement is on a level or downward, and the work can be carried on with a minimum of manual effort.

The plant should be installed so that the different operations may be carried through in a logical sequence, without interruption or interference. Local conditions will determine the relative positions of the several parts of the plant. It is obviously impossible to suggest arrangements applicable to all conditions, but the layouts and routing diagrams shown in connection with the different plants described should assist materially in planning an efficient arrangement.

The fumes from boiling lime-sulphur will discolor lead-and-oil paint and cause it to peel off. The plant, therefore, should be situated far enough away from painted buildings to avoid this.

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